PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : F01N 7/18 — A1

(11) International Publication Number: **WO 99/02826**

(43) International Publication Date: 21 January 1999 (21.01.99)

(21) International Application Number: PCT/US98/13451

(22) International Filing Date: 29 June 1998 (29.06.98)

(30) Priority Data:
08/888,479 7 July 1997 (07.07.97) US

(71) Applicant: NELSON INDUSTRIES, INC. [US/US]; 1802 Highway 51, West, Stoughton, WI 53589 (US).

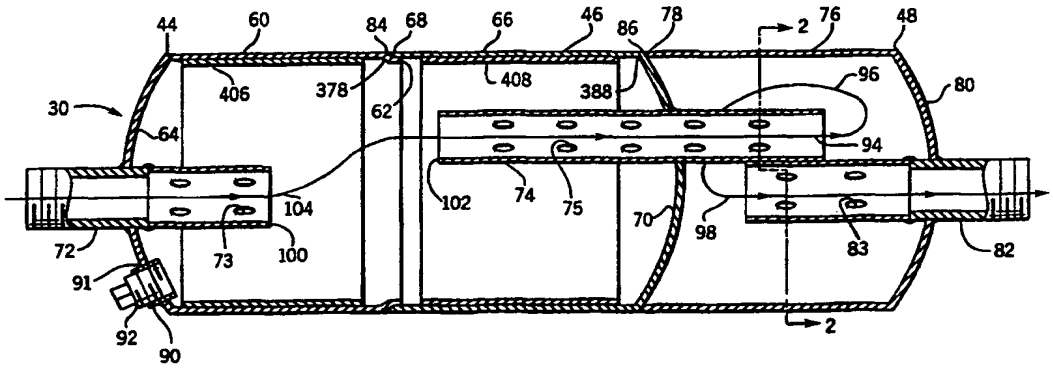
(72) Inventors: BATEMAN, Ralph; 54 Timber Trail, Montello, WI 53949 (US). BRUMM, Craig, S.; 7727 North Morning Meadow Lane, Evansville, WI 53536 (US). CUMMINS, Jim, R., Jr.; 2514 Bigler Circle, Verona, WI 53593 (US). ERIKSSON, Larry, J.; 6105 Fairfax Lane, Madison, WI 53718 (US). GREENER, Charles, M.; 14701 Irish Ridge Road, Mount Hope, WI 53816 (US). KENDZIERA, Ronald, W.; 17892 Circle Drive, Boscobel, WI 53805 (US).

(74) Agents: TAKEN, Michael, E. et al.; Andrus, Sceales, Starke & Sawall, LLP, Suite 1100, 100 East Wisconsin Avenue, Milwaukee, WI 53202 (US).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: MODULAR SILENCER



(57) Abstract

A modular silencer (30) is formed by drawn pots (44, 46) as building blocks in various constructions, components, and methods. Various internal axial, lateral and reversing paths are provided together with multiple compartments and enclosures. Simplified assembly and insulation installation techniques are provided.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

MODULAR SILENCER

BACKGROUND AND SUMMARY

The invention relates to silencers, and more particularly to economical silencer constructions, components, and methods.

Silencers are used in various applications for quieting noise, including mufflers for internal combustion engines, and including other devices such as rotary blowers, compressors, pumps, and the like. Silencers may be used on intake and/or exhaust systems, and may pass various intake and/or exhaust fluids therethrough, including gas and liquid.

Silencers are typically characterized by complex constructions and labor intensive manufacturing methods, particularly welding, all contributing to high cost. The present invention provides simplified constructions and methods in combination with a modular building block approach, to lower cost. The invention also provides simplified, cost effective insulation techniques.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view of a silencer constructed in accordance with the invention.

Fig. 2 is a sectional view taken along line 2-2 of Fig. 1.

Fig. 3 is a view of a portion of the structure of Fig. 1 and shows a further embodiment.

Fig. 4 is a sectional view of a silencer constructed in accordance with the invention.

Fig. 5 is a sectional view of a silencer constructed in accordance with the invention.

Fig. 6 is a sectional view of a silencer constructed in accordance with the invention.

Fig. 7 is a sectional view taken along line 7-7 of Fig. 6.

Fig. 8 is a sectional view of a silencer constructed in accordance with the invention.

Fig. 9 is a sectional view of a silencer constructed in accordance with the invention.

Fig. 10 is a sectional view of a silencer constructed in accordance with the invention.

Figs. 11-20 sequentially illustrate manufacturing steps for constructing a silencer

component.

Figs. 21-23 sequentially illustrate an insulation technique.

Fig. 24 is an exploded perspective view of the structure of Fig. 1.

Fig. 25 is an assembled perspective view of the structure of Fig. 1.

Fig. 26 is a sectional view of a silencer component.

Fig. 27 is a sectional view of a plug silencer constructed in accordance with the invention.

Fig. 28 is like Fig. 27 and shows a further embodiment.

Fig. 29 is a sectional view of a spark arrestor silencer constructed in accordance with the invention.

Fig. 30 is a sectional view taken along line 30-30 of Fig. 29.

Fig. 31 is a sectional view taken along line 31-31 of Fig. 30.

Fig. 32 is a sectional view of a spark arrestor silencer constructed in accordance with the invention.

Fig. 33 is a sectional view taken along line 33-33 of Fig. 32.

Fig. 34 is a sectional view of an aspirating silencer constructed in accordance with the invention.

Fig. 35 is a sectional view of a catalytic silencer constructed in accordance with the invention.

Fig. 36 is like Fig. 35 and shows a further embodiment.

Fig. 37 is like Fig. 35 and shows a further embodiment.

Fig. 38 is a sectional view of a heat recovery silencer constructed in accordance with the invention.

Fig. 39 is a sectional view of a silencer constructed in accordance with the invention.

DETAILED DESCRIPTION

Fig. 1 shows a modular silencer or muffler 30 constructed in accordance with the invention, including a plurality of axially aligned drawn pots. Draw forming of pots is known in the prior art, for example as shown in U.S. Patent 5,020,631, incorporated herein by reference, and is briefly illustrated in Figs. 11 and 12. A flat sheet of metal 32, Fig. 11, is gradually and repetitively deformed and cold flowed by a mandrel to a pot or can 34 as shown in Fig. 12. The pot is trimmed to a desired length by knife blade 36, Fig. 13. Pot 34 has an axially extending continuous sidewall 38 open at one end 40 and having an integral dome head

42 at the other axial end. Fig. 1 shows first, second and third axially aligned drawn pots 44, 46, 48. Pot 48 is formed as above described and then further by punching a hole through its dome head with punch 50, Fig. 15, and then inserting a pipe 52, Fig. 16, through such hole and welding the pipe to the dome head of the pot by welding gun 54. Pot 46, Fig. 1, is similarly made, except that the hole in the dome head is punched at a location laterally offset from the axial centerline, for example as shown at the middle pot in Fig. 24. Pot 44 is similarly constructed as pot 48, except that an additional step, Fig. 14, is provided wherein a tool 56 swages, necks or joggles the open end of the pot to a reduced diameter at 58. The swaging enables telescoped nesting engagement of pots 44 and 46, to be described. In an alternate embodiment, pot 46 is swaged at its open end rather than pot 44, to provide the telescoped nesting engagement.

The construction in Fig. 1 includes first and second axially aligned drawn pots 44 and 46. Pot 44 has an axially extending continuous sidewall 60 initially open at axial end 62 and having an integral dome head 64 at the other axial end. Pot 46 has an axially extending continuous sidewall 66 initially open at axial end 68 and having an integral dome head 70 at the other axial end. Inlet pipe 72 extends axially through dome head 64 along the axial centerline of the pots. In an alternate embodiment, inlet pipe 72 extends axially through dome head 64 and is laterally offset from the axial centerline of the pots. In another alternate embodiment, inlet pipe 72 extends through dome head 64 at an angle relative to the axial centerline of the pots, for example 30° or some other angle. In the latter embodiment, the inlet pipe intersects the dome head at a point laterally offset from the axial centerline of the pots. Intermediate connecting pipe 74 extends axially through dome head 70 and is laterally offset from the axial centerline of the pots, Figs. 1 and 2. The construction of Fig. 1 further includes a third axially aligned drawn pot 48 having an axially extending continuous sidewall 76 initially open at axial end 78 and having an integral dome head 80 at the other axial end. Outlet pipe 82 extends axially through dome head 80 along the axial centerline of the pots. In alternate embodiments, pipe 82 may be laterally offset from the axial centerline of the pots, or may extend at an angle relative to such centerline, as above described in conjunction with pipe 72. The pots are welded together by circumferential weldments 84 and 86 at the respective interfaces of the pots by welder 88, Fig. 25. Further in Fig. 1, dome head 64 has another hole punched therethrough, with a sleeve 90 inserted therein and welded thereto at weldment 91 and receiving a drain plug 92 in threaded relation. Pipe 74 has a plurality of perforations such as 75 through the sidewall thereof. Pipes 72 and 82 have perforations such as 73 and 83 along the portions thereof within

the pots. The exterior portions of pipes 72 and 82 are solid, and are threaded for connection to other components or piping as desired.

In Fig. 1, pipe 74 is laterally offset from pipe 72 and is laterally offset from pipe 82. Pipes 74 and 82 are axially overlapped such that fluid, gas or liquid, inlet or exhaust, flows axially in one direction, e.g. rightwardly in Fig. 1, along path 94, then reverses itself and flows axially in the opposite direction along path 96 laterally adjacent path 94, and then reverses itself again and flows axially rightwardly along path 98 laterally adjacent paths 94 and 96. Path 94 is through pipe 74 through dome head 70. Path 98 is through pipe 82 through dome head 80. Pipes 72 and 74 have axial ends 100 and 102, respectively, axially spaced from each other in nonoverlapping relation such that fluid may flow at 104 from axial end 100 of pipe 72 to axial end 102 of pipe 74 without reversing itself. Pipes 72 and 82 are axially spaced from each other on axially distally opposite sides of pipe 74.

Fig. 3 shows a further embodiment of the construction of Fig. 1. Flanges 104 and 106 are welded to the ends of respective pipes 72 and 82, to facilitate mounting in flanged installations.

Fig. 4 shows a silencer 110 with first, second, third and fourth axially aligned drawn pots 112, 114, 116, 118. Inlet pipe 120 extends axially through dome head 122 of pot 112 along the axial centerline thereof. Intermediate connecting pipe 124 extends axially through dome head 126 of pot 114 along the axial centerline thereof. Intermediate connecting pipe 128 extends axially through dome head 130 of pot 116 and is laterally offset from the axial centerline of the pots. Outlet pipe 132 extends axially through dome head 134 of pot 118 along the axial centerline thereof. Axial ends 136 and 138 of respective pipes 124 and 128 are axially overlapped. All of the remaining axial ends of the pipes are axially spaced from each other in nonoverlapping relation.

Fig. 5 shows a silencer 140 having first, second and third axially aligned drawn pots 142, 144, 146. Inlet pipe 148 extends axially through dome head 150 of pot 142 along the axial centerline thereof, and through insulation 152, to be described. Intermediate connecting pipe 154 extends axially through dome head 156 of pot 144 and is laterally offset from the axial centerline of the pots. Outlet pipe 158 extends axially through dome head 160 of pot 146 along the axial centerline thereof. In Fig. 5, there is no axial overlapping of the pipes, and the axial ends of all the pipes are axially spaced from each other in nonoverlapping relation.

Fig. 6 shows a silencer 162 having first, second and third axially aligned drawn pots 164, 166, 168. Inlet pipe 170 extends axially through dome head 172 of pot 164 along the

axial centerline thereof. A pair of intermediate connecting pipes 174 and 176, Fig. 7, extend through dome head 178 of pot 166 and are each laterally offset from the axial centerline of the pots. Pipes 174 and 176 are further supported by a cross brace 180 welded therebetween. Outlet pipe 182 extends axially through dome head 184 of pot 168 along the axial centerline thereof. Pipes 170 and 182 are axially spaced from each other on axially distally opposite sides of pipes 174 and 176. Pipes 174 and 176 are laterally offset from pipes 170 and 182. Pipes 174 and 176 extend in parallel laterally spaced relation, each having an axial end 186 axially spaced from axial end 188 of pipe 170 in nonoverlapping relation. Pipes 174 and 176 have an axial end 190 axially spaced from axial end 192 of pipe 182 in nonoverlapping relation.

Fig. 8 shows a silencer 200 having first, second, third and fourth drawn pots 202, 204, 206, 208, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end. Pot 202 concentrically surrounds pot 204. Pot 206 concentrically surrounds pot 208. Pots 202 and 206 are coaxially aligned and joined at their open ends 210 and 212 to form a first enclosure 214. Pots 204 and 208 are coaxially aligned and joined at their open ends 216 and 218 to form a second enclosure 220 within enclosure 214. Inlet pipe 222 extends axially through dome head 224 of pot 202 and through dome head 226 of pot 204 along the axial centerline thereof. Outlet pipe 228 extends axially through dome head 230 of pot 206 and through dome head 232 of pot 208 along the axial centerline thereof. Pipes 222 and 228 have inner axial ends 234 and 236, respectively, within enclosure 220 and axially spaced from each other in nonoverlapping relation. Dome head 224 of pot 202 is axially spaced from dome head 226 of pot 204 by an axial gap 225 which is spanned by pipe 222. Dome head 230 of pot 206 is axially spaced from dome head 232 of pot 208 by an axial gap 231 which is spanned by pipe 228. Pots 204 and 208 are perforated along their sidewalls 238 and 240. Pots 202 and 206 forming enclosure 214 are coaxial with pots 204 and 208 forming enclosure 220. Enclosure 220 is spaced radially inwardly of enclosure 214 by an annular gap 215.

Fig. 9 shows a silencer 250 including first, second, third and fourth axially aligned drawn pots 252, 254, 256, 258, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end. Pots 252 and 254 are connected at their open ends 260 and 262 to form a first compartment 264. Pots 256 and 258 are connected at their open ends 266 and 268 to form a second compartment 270. An intermediate cylindrical sidewall 272 extends axially between pots 254 and 256. Intermediate cylindrical sidewall 272 has a leftward axial end 274 connected to the junction of cylindrical

250 forms a third compartment

pot 252 along the axial centerline thereof and into compartment 264. Outlet pipe 292 extends axially through dome head 294 of pot 258 along the axial centerline thereof and into compartment 270. Outlet or inlet pipe 296 extends radially through intermediate cylindrical sidewall 272 and into compartment 286. Intermediate connecting pipe 298 extends axially through dome head 278 of pot 254 and is laterally offset from the axial centerline thereof. Pipe 298 extends between compartments 286 and 264 and communicates with pipe 288 in compartment 264. Intermediate connecting pipe 300 extends axially through dome head 284 of pot 256 and is laterally offset from the axial centerline thereof. Pipe 300 extends between compartments 286 and 270 and communicates with pipe 292 in compartment 270. Pipes 296, 298 and 300 communicate with each other in compartment 286.

Fig. 10 shows a silencer 310 including first, second and third axially aligned drawn pots 312, 314, 316, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end. A fourth drawn pot 318 has a continuous sidewall 320 initially open at one end 322 and having an integral dome head 324 at the other end. End 322 of pot 318 is connected to sidewall 326 of pot 316 and extends laterally away therefrom. Open end 328 of pot 312 is connected to open end 330 of pot 314. Open end 332 of pot 316 is connected to the junction of sidewall 334 and dome head 336 of pot 314. Sidewall 320 of pot 318 is connected to sidewall 326 of pot 316 along an arcuate interface as shown in dashed line at 338. Outlet pipe 340 extends axially through dome head 342 of pot 312 along the axial centerline thereof. Intermediate connecting pipe 344 extends axially through dome head 336 of pot 314 and is laterally offset from the axial centerline thereof. Dome head 346 of pot 316 does not have an inlet pipe therethrough. Intermediate connecting pipe 348 extends laterally through sidewall 326 of pot 316. Inlet pipe 350 extends through dome head 324 of pot 318.

In various of the embodiments shown above, a first pot, such as 360, Fig. 14, has a main body portion 362 of a first diameter 364, and an open end portion 366 of a second smaller diameter 368. A second pot 370, Fig. 15, is not necked by tool 56 and has both its main body portion 372 and its open end portion 374 of the noted first diameter 364. As shown above, such pots are axially overlapped in nesting telescoped relation, for example as shown at

ends 62 and 68 in Fig. 1, ends 210 and 212, and 216 and 218, in Fig. 8, ends 260 and 262, and 266 and 268, in Fig. 9, ends 330 and 328 in Fig. 10, and in other figures. Sidewall 362, Fig. 14, of pot 360 has a transition portion 376 between main body portion 362 and open end portion 366. When pots 360 and 370 are nested, open end 374 of pot 370 axially faces transition portion 376 of pot 360, for example as shown in Fig. 1 at end 68 of sidewall 66 of pot 46 axially facing transition portion 378 of sidewall 60 of pot 44 and connected thereto by weldment 84 at such interface. Sidewall 362, Fig. 14, of pot 360 meets dome head 380 of pot 360 at a junction 382, which junction is circumferential and is of the noted diameter 364. Sidewall 372 of pot 370 meets dome head 384 of pot 370 at junction 386, which junction is circumferential and has the noted diameter 364. This is desirable for various of the above shown mounting arrangements wherein the open end of a pot meets and is joined to the closed dome head end of another pot, for example as shown in Fig. 1 where open end 78 of sidewall 76 of pot 48 abuts the junction 388 of sidewall 66 and dome head 70 of pot 46 and is connected thereto at weldment 86 at such interface. The difference between diameters 364 and 368 is preferably twice the thickness of the sidewall 372 of pot 370, to enable a flush fit outer axially extending surface after assembly.

Figs. 17-20 show various insulation installation methods. In one embodiment, a cylindrical metal liner 400 is inserted into pot 402 and welded thereto by a welding gun 404, Fig. 18. This liner is shown in various of the above figures, for example at 406, 408 in Fig. 1, 410, 412, 414 in Fig. 4, 416 in Fig. 5, 418 in Fig. 6. In another embodiment, with or without liner 400, a preformed annular insulation cartridge 420, Fig. 17, is inserted into pot 402 through open end 422. Cartridge 420 is axially slid along pipe 424 into engagement with dome head 426, Fig. 19. Annular disc or plate 428 is then inserted and welded to pipe 424 by weld gun 430. This insulation package is also shown in Figs. 5 and 6.

In an alternate embodiment, a plurality of annular disc like cartridges or donuts 432, 434, 436, etc., Fig. 17, are serially inserted one after the other into pot 402, with or without liner 400, through open end 422, and axially slid along pipe 424 to form a stack of donuts, Fig. 20, circumferentially surrounding the pipe, followed by insertion and welding of plate 428 as above. The donuts have different shape. Annular donut 432 has a central aperture 438 for receiving pipe 424, a first domed arcuate side 440 conforming to dome head 426, and a second flat side 442. Second annular donut 434 has a central aperture 444 for receiving pipe 424, a first flat side 446 for mating against flat side 442 of donut 432, and a second flat side 448. Further donuts as desired, such as 436, each have a central aperture 450 for receiving pipe 424.

a first flat side 452 for mating against the preceding donut such as 434, and a second flat side 454 for mating against the succeeding donut. Pipe 424 is inserted through dome head 426 prior to insertion of the donuts into pot 402. First donut 432 is inserted into pot 402, and the aperture 438 of donut 432 is slid along pipe 424 until domed arcuate side 440 of donut 432 engages dome head 426. Second donut 434 is inserted into pot 402, and aperture 444 of donut 434 is slid along pipe 424 until flat side 446 of donut 434 engages flat side 442 of donut 432. The next donut such as 436 is inserted into pot 402, and aperture 450 of such donut is slid along pipe 424 until flat side 452 engages flat side 448 of donut 434. Donuts are continued to be inserted into the pot along pipe 424 to a desired length to provide a plurality of serially stacked donuts along pipe 424 within pot 402. The donuts are stacked such that each interface between successive donuts defines a plane substantially perpendicular to the axial extension of pipe 424.

In a further embodiment, the donuts 432, 434, 436, etc., Figs. 17 and 20, are provided of differing sound absorption characteristics to provide differing sound absorption across the respective interfaces between donuts such that there is an impedance change at the interface which causes a reactive effect in addition to a resistive effect. In preferred form, this is accomplished by providing different density donuts. In a further embodiment, the series of donuts providing a series of different sound absorption characteristics provide a plurality of interfaces alternating between increasing and decreasing impedance change thereacross, e.g. providing alternate high and low density donuts in series.

Figs. 21-23 show a further insulation installation technique. A spool 460 of continuous filament insulation thread 462 is fed into pot 402 around pipe 424. Thread 462 is drawn from spool 460 and air blown by air nozzle 461 of air gun 464 into pot 402 with or without liner 400. The thread is preferably multi-stranded yarn. Pressurized air is supplied at 466 to the air gun and puffs out the strands of the thread as shown at 468 during blowing into pot 402. Continuous filament thread for insulation is known in the prior art. In the present implementation, the continuous filament is desirable because it eliminates fiber ends which are believed to contribute to deterioration of silencer insulation because the ends tend to disintegrate over time and in response to heat. In one embodiment, vacuum is applied to the pot at 463 from vacuum source 465 to apply vacuum to pot 402 through the perforations 467 in the interior portion of pipe 424 during blowing of thread 462 into pot 402 by air gun 464. The vacuum draws and locates the thread into the pot. After the insulation thread is blown into the pot as shown at 470, Fig. 23, plate 428 is inserted and welded as before. The described blown-in insulation installation technique is particularly desirable from a commercial and manufacturing

standpoint because of the modularity-enhancing characteristics thereof complementing the modularity of the pots and further simplifying construction, reducing part content, and reducing labor cost by providing a less labor intensive manufacturing process and assembly sequence. The technique provides not only the noted commercial and manufacturing advantages, but also improved performance in extended life due to reduction of deterioration and disintegration of insulation.

Fig. 26 shows a modular silencer component 480 including first and second axially aligned drawn pots 482, 484, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end. Pot 482 is within pot 484, to provide a lined double-walled member having a double-walled dome head 486 and a double-walled sidewall 488. Dome head 490 of pot 484 engages dome head 492 of pot 482 in conforming coextensive parallel arcuate relation. Sidewall 494 of pot 484 engages sidewall 496 of pot 482 in conforming parallel concentric relation. Pot 482 is axially inserted fully into pot 484 until dome head 492 of pot 482 engages dome head 490 of pot 484.

Fig. 27 shows a modular plug silencer 502 including an outer pot assembly 503 including axially aligned drawn outer pots 504, 506, 508, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end. Inlet pipe 510 extends axially through dome head 512 of pot 504. Outlet pipe 514 extends axially through dome head 516 of pot 508. A smaller inner drawn pot 518 is within the outer pot assembly and diverts fluid flow from inlet pipe 510 laterally around inner pot 518 as shown at arrows 520, 522. Inner drawn pot 518 has an integral dome head 524, and an axially extending continuous sidewall 526 along which fluid flows axially. Dome head 528 of outer pot 506 provides a dividing wall extending laterally inwardly from the outer pot assembly and supporting inner pot 518 which extends axially through a central aperture 529 in dome head 528. Dome head 528 is perforated, as at 530, 532, to pass fluid flow axially therethrough after being laterally diverted by inner pot 518. Cylindrical sidewall 526 of inner pot 518 is open at the leftward axial end 534 in Fig. 27, and has integral dome head 524 at the rightward axial end. Open axial end 534 of inner pot 518 faces inlet pipe 510. Cylindrical sidewall 526 of inner pot 518 extends from dome head 524 toward open end 534 along an axial direction opposite to the axial direction of fluid flow. Inner pot 518 is mounted between inlet pipe 510 at open end 534 of the inner pot, preferably by welding, and dome head 528 of outer pot 506 at dome head 524 of inner pot 518, preferably by welding. Inlet pipe 510 extends rightwardly through dome head 512 all the way to open end 534 of inner pot 518, and the portion of inlet exhaust pipe 510

cylindrical sidewall 526 of inner pot 518 may extend leftwardly through dome head 512 of pot 504, to provide the inlet pipe, to be described, Fig. 39.

In Fig. 27, inner pot 518 is within outer pot assembly 503 and is spaced laterally inwardly of sidewall 505 of outer pot 504 by a lateral gap 507 permitting fluid flow axially through such gap as shown at arrows 520a and 522a. Inner pot 518 is axially spaced from dome head 512 of outer pot 504 by an axial gap 509 permitting fluid flow laterally through such axial gap as shown at arrows 520b and 522b. This is also illustrated in Fig. 8 where sidewalls 220 and 240 of inner pots 204 and 208 are spaced laterally inwardly of sidewalls 203 and 207 of outer pots 202 and 206 by a lateral gap 215. Dome head 226 of inner pot 204 is spaced axially from dome head 224 of outer pot 202 by axial gap 225. Dome head 232 of inner pot 208 is axially spaced from dome head 230 of outer pot 206 by axial gap 231. Inner pots 204 and 208 are coaxially aligned, and lateral gap 215 defines an annulus through which fluid flows. Annulus 215 has an outer circumference at sidewalls 203 and 207 of outer pots 202 and 206. Annulus 215 has an inner circumference at sidewalls 220 and 240 of inner pots 204 and 208. In Fig. 27, pot 518 is within outer pot 504, and sidewall 526 of inner pot 518 is spaced laterally inwardly of sidewall 505 of outer pot 504 by lateral gap 507 permitting fluid flow axially, at arrows 520a, 522a, through such lateral gap 507. Dome head 524 of inner pot 518 is spaced axially from dome head 512 of outer pot 504 by axial gap 509 permitting fluid flow laterally, at arrows 520b, 522b, through such axial gap 509. Pots 504 and 518 are coaxially aligned, and lateral gap 507 defines an annulus through which fluid flows axially. Annulus 507 has an outer circumference at sidewall 505 of outer pot 504. Annulus 507 has an inner circumference at sidewall 526 of inner pot 518.

Fig. 28 shows a modular plug silencer 540 including an outer pot assembly 541 including axially aligned drawn outer pots 542, 544, 546, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end. Inlet pipe 548 extends axially through dome head 550 of pot 542. Outlet pipe 552 extends axially through dome head 554 of pot 546. Inner drawn pot 556 is within the outer pot assembly and has an axially extending continuous sidewall 558 open at its rightward axial end and has an integral dome head 560 at its leftward axial end. Inner pot 556 diverts fluid flow from inlet pipe 548 laterally around the inner pot as shown at arrows 562, 564. Dome head 566

of outer pot 544 provides a divider wall extending laterally inwardly from the outer pot assembly and supporting inner pot 556. Dome head 566 is perforated, as at 568, 570, and passes fluid flow axially therethrough after being laterally diverted by inner pot 556. Cylindrical sidewall 558 of inner pot 556 extends from dome head 560 toward the rightward open end of the pot along an axial direction the same as the axial direction of fluid flow. In the embodiment in Fig. 28, inner pot 556 is within inlet pipe 548. Dome head 566 of outer pot 544 has a central aperture at 567 receiving pipe 548. The interior portion of pipe 548 is perforated, as at 549. Dome head 566 at aperture 567 is welded around pipe 548, and inner pot 556 is welded within pipe 548. In the embodiment of Fig. 28, a singular through pipe 572 extends through all of the outer pots, including through dome heads 550, 566, 554 of pots 542, 544, 546, respectively, such that the singular through pipe 572 provides both the inlet pipe 548 and the outlet pipe 552.

Fig. 29 shows a modular spark arrestor silencer 580 including an outer pot assembly 581 including axially aligned drawn pots 582, 584, 586, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end. Inlet pipe 588 extends axially through dome head 590 of pot 582. Outlet pipe 592 extends axially through dome head 594 of pot 586. Spin flow structure 596 is provided within the outer pot assembly and imparts a spinning corkscrew motion as shown at 598 to fluid flow from inlet pipe 588 before passage to outlet pipe 592. The spin flow structure includes a plurality of louvers 600 receiving axial fluid flow from inlet pipe 588 and imparting a radial and circumferential component thereto. Dome head 602 of outer pot 584 provides an annular divider wall extending laterally inwardly from the outer pot assembly and supporting the louvers. Dome head 602 directs fluid flow from inlet pipe 588 to the louvers, and blocks reverse fluid flow after passage through the louvers. The spin flow structure is provided by an inner drawn pot 604 within the outer pot assembly. Inner pot 604 has a continuous cylindrical sidewall 606 open at its rightward axial end, and an integral dome head 608 at its leftward axial end. Inner pot 604 extends through central aperture 603 in dome head 602 of outer pot 584, and is mounted thereto by welding. Dome head 608 of inner pot 604 has a plurality of louvers 600 punched therethrough, Figs. 29-31. The louvers receive axial fluid flow from inlet pipe 588 and impart the noted radial and circumferential component thereto. Dome head 608 axially faces inlet pipe 588, and cylindrical sidewall 606 of inner pot 604 extends axially from dome head 608 to the rightward open axial end of the inner pot along the same axial direction as fluid flow. The spinning corkscrew motion imparted to fluid flow by louvers 600 as shown at arrow 598

Figs. 32 and 33 show an alternate embodiment

and use like reference numerals where appropriate to facilitate understanding. Instead of punching the louvers through dome head 608 of inner pot 604, louvers 605 instead are punched through sidewall 606 of inner pot 604, to impart a radial and circumferential component to the fluid flow, and provide the noted spinning corkscrew motion to carry spark debris into inner pot 604 along cylindrical sidewall 606 and through the rightward open end of the inner pot into outer pot 586 for collection and clean-out, as above.

Fig. 34 shows a modular aspirating silencer 620 including a pot assembly 621 including axially aligned drawn pots 622, 624, 626, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end. Inlet pipe 628 extends axially through dome head 630 of pot 622. Outlet pipe 632 extends axially through dome head 634 of pot 626. A converging cone 636 within the pots provides a venturi 638. An aspiration inlet 640 into the pot assembly aspirates venturi 638. Dome head 642 of pot 624 has an opening punched therethrough along a frustoconically tapered sidewall 644 providing the converging cone. The aspiration inlet includes an aspiration pipe 646 extending through dome head 642 of pot 624. Frustoconically tapered sidewall 644 tapers from an upstream diameter to a smaller downstream diameter. Outlet exhaust pipe 632 is axially aligned with convergence cone 636 and has a larger diameter than the noted downstream diameter of frustoconically tapered sidewall 644.

Fig. 35 shows a modular catalytic silencer 650 including a pot assembly 651 including axially aligned drawn pots 652, 654, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end. Inlet pipe 656 extends axially through dome head 658 of pot 652. Outlet pipe 660 extends axially through dome head 662 of pot 654. Catalytic media 664 is provided in at least one of the pots, either in the form of a known catalytic monolith or known catalytic beads.

Fig. 36 shows a modular catalytic silencer 670 including a pot assembly 671 including axially aligned drawn pots 672, 674, 676, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end. Inlet pipe 678 extends axially through dome head 680 of pot 672. Outlet pipe 682 extends axially through dome head 684 of pot 676. Dome head 686 of pot 674 is at the open end of pot

676. Catalytic media 688 is in pot 676. Dome head 686 of pot 674 has a plurality of laterally spaced openings or perforations 690 therethrough for fluid flow distribution to catalytic media 688 in pot 676.

Fig. 37 shows a modular catalytic silencer 702 including a pot assembly 703 including axially aligned drawn pots 704, 706, 708, 710, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end. Inlet pipe 712 extends axially through dome head 714 of pot 704. Outlet pipe 716 extends axially through dome head 718 of pot 710. Dome head 720 of pot 706 is at the open end of pot 708. Dome head 722 of pot 708 is at the open end of pot 710. Catalytic media 724 is in pot 708. Dome head 720 of pot 706 has a plurality of laterally spaced openings or perforations 726 therethrough for fluid flow distribution to catalytic media 724 in pot 708. Dome head 722 has a plurality of laterally spaced openings or perforations 728 therethrough for fluid flow distribution from catalytic media 724 in pot 708.

Fig. 38 shows a modular heat transfer silencer 740 including a pot assembly 741 including axially aligned drawn pots 742, 744, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end. Inlet pipe 746 extends axially through dome head 748 of pot 742. Outlet pipe 750 extends axially through dome head 752 of pot 744. Fluid heat exchanger module 754 in the pot assembly has a heat exchanger inlet 756 extending through the pot assembly into heat exchanger 754, and a heat exchanger outlet 758 extending out of the heat exchanger 754 through the pot assembly, to transfer heat between fluid in the pots and fluid in heat exchanger 754. In one embodiment, heat exchanger 754 is a heat recovery module recovering heat from the pot assembly and delivering fluid at heat exchanger outlet 758 at an elevated temperature relative to fluid at heat exchanger inlet 756.

Fig. 39 shows a silencer 770 similar to silencer 502 in Fig. 27, and uses like reference numerals where appropriate to facilitate understanding. Outer pot assembly 772 includes outer pots 506 and 508, as in Fig. 27, and includes a pot 774 with cylindrical sidewall 776 and integral dome head 778. Inner pot 780 includes cylindrical sidewall 782 open at its leftward axial end and having integral dome head 784 at its other axial end. In Fig. 39, cylindrical sidewall 782 of inner pot 780 provides inlet pipe 786. Cylindrical sidewall 782 of inner pot 780 extends from dome head 784 of the inner pot axially leftwardly in Fig. 39 toward the open end of the inner pot axially through dome head 778 of outer pot 774. This eliminates separate inlet pipe 510 in Fig. 27.

It is recognized that various equivalents, alternatives and modifications are possible within the scope of the appended claims. In a desirable aspect of the invention, numerous other combinations of structures and chambers may be mixed and matched. In a further desirable aspect, numerous of the joints or interfaces between the pots may be provided by direct welding of the pots to each other and/or the addition of flange joints at such interfaces which may be welded and/or bolted, the latter facilitating disassembly or removal for clean-out, or the like. Such flange joints can be provided by an annular disc or ring around the pot, or could be provided, for example, by flaring the open end of the pot outwardly to a larger radius. The present invention may be used in combination with conventional silencers, for example by adding pots or chambers on either end of a conventional silencer. The present silencer may be used as a complete stand alone unit, or, for example, may be enclosed within a conventional silencer, or may be provided around and encompassing a conventional silencer.

CLAIMS

1. A modular silencer comprising first and second axially aligned drawn pots, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end, a first pipe extending axially through said dome head of said first pot along the axial centerline thereof, a second pipe extending axially through said dome head of said second pot and laterally offset from the axial centerline thereof.

2. A modular silencer comprising first, second and third axially aligned drawn pots, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end, first, second and third pipes extending axially through a respective said dome head, at least two of said pipes being laterally offset from each other.

3. The silencer according to claim 2 wherein said two pipes are axially overlapped such that fluid flows axially in one direction along a first path, then reverses itself and flows axially in the opposite direction along a second path laterally adjacent said first path, and then reverses itself again and flows axially in said one direction along a third path laterally adjacent said second path.

4. The silencer according to claim 3 wherein:

said first path is through said second pipe through said second dome head;

said third path is through said third pipe through said third dome head;

said first and second pipes have axial ends axially spaced from each other in nonoverlapping relation such that fluid may flow from said axial end of said first pipe to said axial end of said second pipe without reversing itself.

5. The silencer according to claim 2 wherein:

said first and third pipes are axially spaced from each other on axially distally opposite sides of said second pipe;

said second pipe is laterally offset from at least one of said first and second pipes.

6. The silencer according to claim 5 wherein said first and third pipes are axially aligned.

7. The silencer according to claim 2 wherein:

said first and second pipes have axial ends axially spaced from each other in nonoverlapping relation;

said second and third pipes are axially overlapped.

8. The silencer according to claim 2 wherein:

said first and second pipes have axial ends axially spaced from each other in nonoverlapping relation;

said second and third pipes have axial ends axially spaced from each other in nonoverlapping relation.

9. The silencer according to claim 2 comprising:

a fourth pipe extending axially through said dome head of said second pot;

said first and third pipes being axially spaced from each other and on axially distally opposite sides of said second and fourth pipes.

10. The silencer according to claim 9 wherein said second and fourth pipes are laterally offset from said first and third pipes.

11. The silencer according to claim 9 wherein said second and fourth pipes extend in parallel laterally spaced relation, each having an axial end axially spaced from an axial end of said first pipe in nonoverlapping relation.

12. The silencer according to claim 9 wherein:

said first and second pipes have axial ends axially spaced from each other in nonoverlapping relation;

said second and third pipes have axial ends axially spaced from each other in nonoverlapping relation;

said first and fourth pipes have axial ends axially spaced from each other in nonoverlapping relation;

said third and fourth pipes have axial ends axially spaced from each other in nonoverlapping relation.

13. The silencer according to claim 2 comprising:

a fourth drawn pot axially aligned with said first, second and third pots, said fourth pot having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end;

a fourth pipe extending axially through said dome head of said fourth pot.

14. The silencer according to claim 13 wherein:

said open end of said first pot is joined to said open end of said second pot;

said dome head of said second pot is joined to said open end of said third pot;

said dome head of said third pot is joined to said open end of said fourth pot.

15. The silencer according to claim 13 wherein at least two of said pipes are axially aligned, and at least one of the remaining pipes is laterally offset therefrom.

16. The silencer according to claim 15 wherein said first, second and fourth pipes are axially aligned, and said third pipe is laterally offset therefrom.

17. The silencer according to claim 16 wherein:

said first and second pipes have axial ends axially spaced from each other in nonoverlapping relation;

said second and third pipes are axially overlapped;

said second and fourth pipes have axial ends axially spaced from each other in nonoverlapping relation;

said third and fourth pipes have axial ends axially spaced from each other in nonoverlapping relation.

18. A modular silencer comprising first, second, third and fourth drawn pots, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end, said first pot concentrically surrounding said second pot, said third pot concentrically surrounding said fourth pot, said first and third pots being coaxially aligned and joined at their open ends to form a first enclosure, said second and fourth pots being coaxially aligned and joined at their open ends to form a second enclosure within said first enclosure.

19. The silencer according to claim 18 comprising:

a first pipe extending axially through said dome head of said first pot and through said dome head of said second pot;

a second pipe extending axially through said dome head of said third pot and through said dome head of said fourth pot.

20. The silencer according to claim 19 wherein:

said first and second pipes have inner axial ends within said second enclosure and axially spaced from each other in nonoverlapping relation;

said dome head of said first pot is axially spaced from said dome head of said second pot by a first axial gap;

said first pipe spans said first axial gap;

said dome head of said third pot is axially spaced from said dome head of said fourth pot by a second axial gap;

said second pipe spans said second axial gap.

21. The silencer according to claim 18 wherein:

said second and fourth pots are perforated along their sidewall;

said first and third pots forming said first enclosure are coaxial with said second and fourth pots forming said second enclosure;

said second enclosure is spaced radially inwardly of said first enclosure by an annular gap.

22. A modular silencer comprising first, second, third and fourth axially aligned drawn pots, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end, said first and second pots being connected at their open ends to form a first compartment, said third and fourth pots being connected at their open ends to form a second compartment, an intermediate cylindrical sidewall extending axially between said second and third pots, said intermediate cylindrical sidewall having a first axial end connected to said cylindrical sidewall of said second pot at said dome head of said second pot, said intermediate cylindrical sidewall having a second axial end connected to said cylindrical sidewall of said third pot at said dome head of said third pot, to form a third compartment.

23. The silencer according to claim 22 comprising:

a first pipe extending axially through said dome head of said first pot;

a second pipe extending axially through said dome head of said fourth pot;

a third pipe extending radially through said intermediate cylindrical sidewall.

24. The silencer according to claim 23 comprising:

a fourth pipe extending axially through said dome head of said second pot and communicating with said first pipe in said first compartment;

a fifth pipe extending axially through said dome head of said third pot and communicating with said second pipe in said second compartment;

said third, fourth and fifth pipes communicating with each other in said third compartment.

25. A modular silencer comprising a plurality of axially aligned drawn pots, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end, a side pot comprising a drawn pot having a continuous sidewall open at one end and having an integral dome head at the other end, said open end of said side pot being connected to said sidewall of one of said axially aligned pots.

26. The silencer accordingly to claim 25 wherein said sidewall of said side pot extends laterally away from said sidewall of said one of said axially aligned pots.

27. The silencer according to claim 25 wherein said plurality of axially aligned

pots comprises first, second and third axially aligned drawn pots, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end, said side pot comprises a fourth drawn pot having a continuous sidewall open at one end and having an integral dome head at the other end, said open end of said fourth pot being connected to said sidewall of one of said first, second and third pots.

28. The silencer according to claim 27 wherein said sidewall of said third pot is longer than the width of said dome head of said fourth pot, and wherein said open end of said fourth pot is connected to said sidewall of said third pot.

29. The silencer according to claim 27 wherein:

said open end of said first pot is connected to said open end of said second pot;

said open end of said third pot is connected to said dome head of said second pot;

said sidewall of said fourth pot is connected to said sidewall of said third pot along an arcuate interface.

30. The silencer according to claim 29 comprising:

a first pipe extending axially through said dome head of said first pot;

a second pipe extending axially through said dome head of said second pot;

a third pipe extending laterally through said sidewall of said third pot;

a fourth pipe extending through said dome head of said fourth pot.

31. A modular silencer comprising first and second axially aligned drawn pots, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end, the axially extending sidewall of said first pot having a main body portion of a first diameter and an open end portion of a second different diameter at said open axial end of said first pot, the axially extending sidewall of said second pot having an open end portion of said first diameter at said open axial end of said second pot.

32. The silencer according to claim 31 wherein said open ends of said first and second pots are axially overlapped in nesting telescoped relation.

33. The silencer according to claim 32 wherein:

said sidewall of said first pot has a transition portion between said main body portion of said first diameter and said open end portion of said second diameter;

said open end of said second pot axially faces said transition portion of said first pot;

and comprising a weldment at the interface of said open end of said second pot

and said transition portion of said first pot.

34. The silencer according to claim 32 wherein:

said first and second pots are nonidentical;

said sidewall of said second pot has a main body portion of said first diameter, and said open end portion of said first diameter.

35. The silencer according to claim 34 wherein:

said sidewall of said first pot meets said dome head of said first pot at a first junction;

said sidewall of said second pot meets said dome head of said second pot at a second junction;

each of said first and second junctions is of said first diameter.

36. The silencer according to claim 34 wherein said second diameter is less than said first diameter.

37. The silencer according to claim 34 comprising:

a third drawn pot axially aligned with said first and second pots, said third pot having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end;

said sidewall of said third pot having a main body portion of said first diameter, and an open end portion of said first diameter at said open axial end of said third pot;

said open end of said third pot axially abutting said dome head of one of said first and second pots.

38. The silencer according to claim 37 wherein:

said sidewall of said first pot meets said dome head of said first pot at a junction having said first diameter;

said sidewall of said second pot meets said dome head of said second pot at a junction having said first diameter;

said sidewall of said third pot meets said dome head of said third pot at a junction having said first diameter.

39. A modular silencer component comprising first and second axially aligned drawn pots, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end, said first pot being within said second pot to provide a lined double-walled member having a double-walled dome head and a double-walled sidewall.

40. The silencer component according to claim 39 wherein said dome head of said second pot engages said dome head of said first pot in conforming coextensive parallel arcuate relation, and said sidewall of said second pot engages said sidewall of said first pot in conforming parallel concentric relation.

41. A modular silencer component comprising first and second drawn pots, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end, said first pot being within said second pot, with said sidewall of said second pot spaced laterally inwardly of said sidewall of said first pot by a lateral gap permitting fluid flow axially through said lateral gap.

42. The silencer component according to claim 41 wherein said dome head of said second pot is spaced axially from said dome head of said first pot by an axial gap permitting fluid flow laterally through said axial gap.

43. The silencer component according to claim 42 wherein said first and second pots are coaxially aligned, and said lateral gap defines an annulus through which said fluid flows axially, said annulus having an outer circumference at said sidewall of said first pot, said annulus having an inner circumference at said sidewall of said second pot.

44. A modular silencer component comprising an axially drawn pot having an axially continuous sidewall open at one axial end and having an integral dome head at the other axial end, said sidewall having a main body portion of a first diameter, an open end portion of a second diameter at said open axial end of said pot, and a junction portion of a third diameter at the junction of said sidewall and said dome head, said first and third diameters being equal.

45. The silencer component according to claim 44 wherein said first and second diameters are equal.

46. The silencer component according to claim 44 wherein said first and second diameters are different.

47. The silencer component according to claim 46 wherein said second diameter is less than said first diameter.

48. The silencer component according to claim 44 comprising a second axially drawn pot having an axially continuous sidewall open at one axial end and having an integral dome head at the other axial end, said sidewall of said second pot having a main body portion of a fourth diameter, an open end portion of a fifth diameter at said open axial end of said second pot, and a junction portion of a sixth diameter at the junction of said sidewall of said second pot and said dome head of said second pot, wherein:

said first, second, third, fourth and sixth diameters are all equal to each other;

said fifth diameter is different than said first, second, third, fourth and sixth diameters.

49. The silencer component according to claim 48 wherein the difference between said fifth diameter and said first, second, third, fourth and sixth diameters is equal to twice the thickness of said sidewall of the first of said pots.

50. A method for making a modular silencer comprising:

draw forming a plurality of pots, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end;

swaging said sidewall of a first of said pots at said open end to a different diameter;

assembling said first pot and a second of said pots by axially aligning said pots at said open ends and axially sliding said sidewall of said first pot along said sidewall of said second pot to axially overlap said sidewalls along said swaged portion of said sidewall of said first pot.

51. The method according to claim 50 comprising:

swaging said sidewall of said first pot at said open end to a reduced diameter;

axially inserting said first pot partially into said second pot by inserting said swaged open end of said first pot into said second pot.

52. The method according to claim 50 comprising assembling a third of said pots and one of said first and second pots by axially aligning said dome head of said one of said first and second pots and said open end of said third pot and axially moving them toward each other until said sidewall of said third pot at said open end engages the junction of said dome head and said sidewall of said one of said first and second pots, without axial overlap of said sidewalls of said third pot and said one of said first and second pots.

53. A method for making a modular silencer comprising draw forming a plurality of pots, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end, axially inserting one of said pots fully into another of said pots until said dome head of said one pot engages said dome head of said other pot to provide a lined double-walled member having a double-walled dome head and a double-walled sidewall.

54. A method for making a modular silencer component comprising draw forming a pot having an axially extending continuous sidewall open at one axial end and having

an integral dome head at the other axial end, axially inserting a preformed annular insulation cartridge into said pot through said open end.

55. The method according to claim 54 comprising:

punching a hole axially through said dome head;

inserting a pipe axially through said hole in said dome head;

axially sliding said cartridge along said pipe.

56. The method according to claim 55 comprising:

providing a plurality of said cartridges in the form of donuts;

inserting said donuts one after the other serially into said pot through said open end;

axially sliding said donuts along said pipe to form a stack of donuts circumferentially surrounding said pipe.

57. The method according to claim 56 comprising providing different shape said donuts, including:

a first annular donut having a central aperture for receiving said pipe, a first domed arcuate side conforming to said dome head, and a second flat side;

a second annular donut having a central aperture for receiving said pipe, a first flat side for mating against said second flat side of said first donut, and a second flat side;

further donuts as desired, each having a central aperture for receiving said pipe, a first flat side for mating against the preceding donut, and a second flat side for mating against the succeeding donut;

and comprising:

inserting said pipe through said dome head prior to insertion of said cartridges into said pot;

inserting said first donut into said pot and sliding said aperture of said first donut along said pipe until said first domed arcuate side of said first donut engages said dome head;

inserting said second donut into said pot and sliding said aperture of said second donut along said pipe until said first flat side of said second donut engages said second flat side of said first donut;

inserting the next donut into said pot and sliding the aperture of said next donut along said pipe until said first flat side of said next donut engages said second side of said second donut;

continuing to insert donuts into said pot and sliding said donuts along said pipe

to a desired length to provide a plurality of serially stacked donuts along said pipe within said pot;

stacking said donuts along said pipe such that each interface between successive donuts defines a plane substantially perpendicular to the axial extension of said pipe.

58. The method according to claim 56 comprising providing differing sound absorption characteristic said donuts to provide differing sound absorption across an interface between donuts such that there is an impedance change at said interface causing a reactive effect in addition to a resistive effect.

59. The method according to claim 58 comprising providing a series of different sound absorption characteristic said donuts providing a plurality of said interfaces alternating between increasing and decreasing impedance change thereacross.

60. A method for making a modular silencer comprising draw forming a plurality of pots, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end, punching a hole axially through said dome head, inserting a pipe axially through said hole in said dome head, providing a spool of continuous filament insulation thread and feeding said thread into said pot around said pipe.

61. The method according to claim 60 comprising drawing said thread from said spool and air blowing said thread into said pot.

62. The method according to claim 61 comprising providing multi-stranded yarn-like said thread and blowing said thread into said pot through an air nozzle and puffing out the strands of said thread during said blowing into said pot.

63. The method according to claim 62 comprising drawing and locating said thread into said pot by applying vacuum to said pot during said blowing of said thread into said pot.

64. A modular silencer component comprising an axially drawn pot having an axially continuous sidewall open at one axial end and having an integral dome head at the other axial end, a pipe extending axially through said dome head, a preformed annular insulation cartridge in said pot around said pipe.

65. The silencer component according to claim 64 wherein said preformed annular insulation cartridge comprises a plurality of donuts concentrically surrounding said pipe and axially stacked in series along said pipe.

66. The silencer component according to claim 65 wherein said donuts have different shape, and comprise:

a first annular donut having a central aperture for receiving said pipe, a first domed arcuate side conforming to said dome head, and a second flat side;

a second annular donut having a central aperture for receiving said pipe, a first flat side for mating against said second flat side of said first donut, and a second flat side;

further donuts as desired, each having a central aperture for receiving said pipe, a first flat side for mating against the preceding donut, and a second flat side for mating against the succeeding donut;

said donuts being stacked along said pipe within said pot such that each interface between successive donuts defines a plane substantially perpendicular to the axial extension of said pipe.

67. A modular silencer comprising a pot having an axial sidewall open at one axial end and having a dome head at the other axial end, a plurality of insulation cartridges axially stacked in series in said pot, said cartridges having differing sound absorption characteristics to provide differing sound absorption across an interface between cartridges such that there is an impedance change at said interface causing a reactive effect in addition to a resistive effect.

68. The silencer component according to claim 67 comprising a pipe extending axially through said dome head, and wherein said cartridges comprise donuts concentrically surrounding said pipe and axially stacked in series along said pipe.

69. The silencer component according to claim 68 wherein said donuts comprise a series of different sound absorption characteristic said donuts providing a plurality of said interfaces alternating between increasing and decreasing impedance change thereacross.

70. The silencer component according to claim 68 wherein said donuts have differing density.

71. A modular plug silencer comprising an outer pot assembly comprising a plurality of axially aligned drawn outer pots, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end, an inlet pipe extending into said outer pot assembly, an outlet pipe extending out of said outer pot assembly, an inner pot within said outer pot assembly.

72. The plug silencer according to claim 71 wherein said inner pot is spaced laterally inwardly of said sidewall of a first of said outer pots by a lateral gap permitting fluid flow axially through said lateral gap, and wherein said inner pot is spaced axially from said dome head of said first outer pot by an axial gap permitting fluid flow laterally through said

axial gap.

73. The plug silencer according to claim 72 wherein said inlet pipe extends axially through said dome head of said first outer pot, and wherein said inner pot diverts fluid flow from said inlet pipe laterally around said inner pot.

74. The plug silencer according to claim 73 wherein said inner pot comprises a dome head, and a cylindrical sidewall along which exhaust flows axially.

75. The plug silencer according to claim 74 comprising an annular perforated divider wall extending laterally inwardly from said outer pot assembly and supporting said inner pot, the perforations through said divider wall passing fluid flow axially therethrough after being laterally diverted by said inner pot.

76. The plug silencer according to claim 75 wherein said divider wall is comprised of said dome head of a second of said outer pots.

77. The plug silencer according to claim 74 wherein said cylindrical sidewall of said inner pot is open at one axial end and has said dome head at the other axial end, said open axial end of said inner pot faces said inlet pipe, said cylindrical sidewall of said inner pot extending from said dome head toward said open end along an axial direction opposite to the axial direction of fluid flow.

78. The plug silencer according to claim 77 wherein said inner pot is mounted between said inlet pipe at said open end of said inner pot, and said dome head of a second of said outer pots at said dome head of said inner pot.

79. The plug silencer according to claim 74 wherein said cylindrical sidewall of said inner pot is open at one axial end and has said dome head at the other axial end, said cylindrical sidewall of said inner pot extending from said dome head toward said open end along an axial direction the same as the axial direction of fluid flow.

80. The plug silencer according to claim 74 wherein said inner pot is within said inlet pipe.

81. The plug silencer according to claim 80 comprising an annular divider wall extending laterally between said outer pot assembly and said inlet pipe, said divider wall and said inlet pipe each being perforated.

82. The plug silencer according to claim 81 wherein said divider wall is comprised of said dome head of a second of said outer pots.

83. The plug silencer according to claim 82 comprising a through pipe extending through all of said outer pots, including through respective dome heads of distally

opposite outer pots, and through said perforated dome head of said second outer pot, such that said through pipe provides both said inlet pipe and said outlet pipe.

84. The plug silencer according to claim 71 wherein said inner pot comprises a cylindrical sidewall open at one end and having a dome head at the other end, said cylindrical sidewall providing said inlet pipe.

85. The plug silencer according to claim 84 wherein said cylindrical sidewall of said inner pot extends from said dome head of said inner pot toward said open end of said inner pot axially through said dome head of a first of said outer pots.

86. The plug silencer according to claim 85 wherein said cylindrical sidewall of said inner pot extends from said dome head of said inner pot toward said open end of said inner pot along an axial direction opposite to the axial direction of fluid flow.

87. A modular spark arrestor silencer comprising an outer pot assembly comprising a plurality of axially aligned drawn outer pots, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end, an inlet pipe extending into said outer pot assembly, an outlet pipe extending out of outer pot assembly, spin flow structure within said outer pot assembly imparting a spinning motion to fluid flow from said inlet pipe before passage to said outlet pipe.

88. The spark arrestor silencer according to claim 87 wherein said spin flow structure comprises a plurality of louvers receiving fluid flow from said inlet pipe and imparting a radial and circumferential component thereto.

89. The spark arrestor silencer according to claim 88 comprising an annular divider wall extending laterally inwardly from said outer pot assembly and supporting said louvers, said divider wall directing fluid flow to said louvers, and blocking reverse fluid flow after passage through said louvers.

90. The spark arrestor silencer according to claim 89 wherein said divider wall is comprised of said dome head of a second of said outer pots.

91. The spark arrestor silencer according to claim 87 wherein said spin flow structure is provided by an inner pot within said outer pot assembly, said inner pot having a cylindrical sidewall and a dome head, said inner pot having a plurality of louvers formed therein, said louvers receiving fluid flow from said inlet pipe and imparting a spinning corkscrew component thereto.

92. The spark arrestor silencer according to claim 91 wherein said cylindrical sidewall of said inner pot is open at one axial end and has said dome head at the other axial end,

said cylindrical sidewall of said inner pot extends axially from said dome head to said open end along the same axial direction as fluid flow, wherein the spinning corkscrew motion imparted to said fluid flow by said louvers carries spark debris into said inner pot along said cylindrical sidewall of said inner pot and through said open end of said inner pot into an outer pot for collection and clean-out.

93. The spark arrestor silencer according to claim 92 wherein said inner pot extends axially through said dome head of a second of said outer pots.

94. The spark arrestor silencer according to claim 91 wherein said louvers are punched through said dome head of said inner pot and impart a radial and circumferential component to said fluid flow.

95. The spark arrestor silencer according to claim 91 wherein said louvers are punched in said sidewall of said inner pot and impart a radial and circumferential component to said fluid flow.

96. A modular aspirating silencer comprising a pot assembly comprising a plurality of axially aligned drawn pots, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end, an inlet pipe extending into said pot assembly, an outlet pipe extending out of said pot assembly, a venturi in said pot assembly, an aspiration inlet into said pot assembly and aspirating said venturi.

97. The aspirating silencer according to claim 96 comprising a converging cone within said pot assembly providing said venturi.

98. The aspirating silencer according to claim 97 wherein said plurality of pots comprises first, second and third axially aligned drawn pots, said second pot being axially between said first and third pots, said dome head of said second pot having an opening punched therethrough along a frustoconically tapered sidewall providing said converging cone.

99. The aspirating silencer according to claim 98 wherein said aspiration inlet comprises an aspiration pipe extending through said dome head of at least one of said pots.

100. The aspirating silencer according to claim 98 wherein said frustoconically tapered sidewall tapers from an upstream diameter to a smaller downstream diameter, and wherein said outlet pipe is axially aligned with said convergence cone and has a larger diameter than said downstream diameter of said frustoconically tapered sidewall.

101. A modular catalytic silencer comprising a pot assembly comprising a plurality of axially aligned drawn pots, each having an axially extending continuous sidewall open at one axial end and having an integral dome head at the other axial end, an inlet pipe

extending into said pot assembly, an outlet pipe extending out of said pot assembly, catalytic media in at least one of said pots.

102. The catalytic silencer according to claim 101 comprising a first said pot upstream of a second said pot, and wherein:

said dome head of said first pot is at said open end of said second pot;

said catalytic media is in said second pot;

said dome head of said first pot has a plurality of laterally spaced openings therethrough for fluid flow distribution to said catalytic media in said second pot.

103. The catalytic silencer according to claim 102 comprising a third said pot downstream of said second pot, and wherein:

said dome head of said second pot is at said open end of said third pot;

said dome head of said second pot has a plurality of laterally spaced openings therethrough for fluid flow distribution from said catalytic media in said second pot.

104. A modular heat transfer silencer comprising a pot assembly comprising a plurality of axially aligned pots, each having an axially extending sidewall open at one axial end and having a dome head at the other axial end, an inlet pipe extending into said pot assembly, an outlet pipe extending out of said pot assembly, a heat exchanger in said pot assembly and having a heat exchanger inlet extending through said pot assembly into said heat exchanger, and a heat exchanger outlet extending out of said heat exchanger through said pot assembly, to transfer heat between fluid in said pots and fluid in said heat exchanger.

105. The heat transfer silencer according to claim 104 wherein said heat exchanger comprises a heat recovery module in said pot assembly and recovering heat from said pot assembly and delivering fluid at said heat exchanger outlet at an elevated temperature relative to fluid at said heat exchanger inlet.

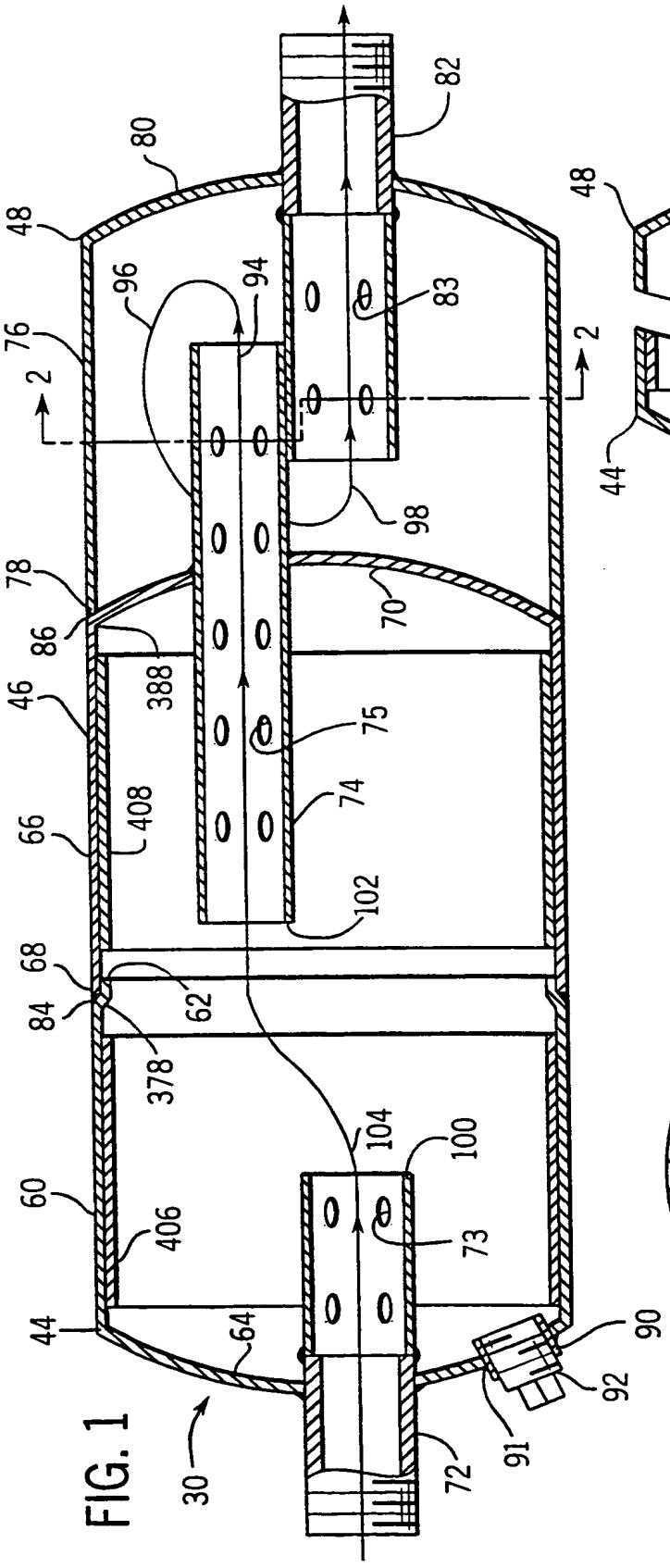


FIG. 1

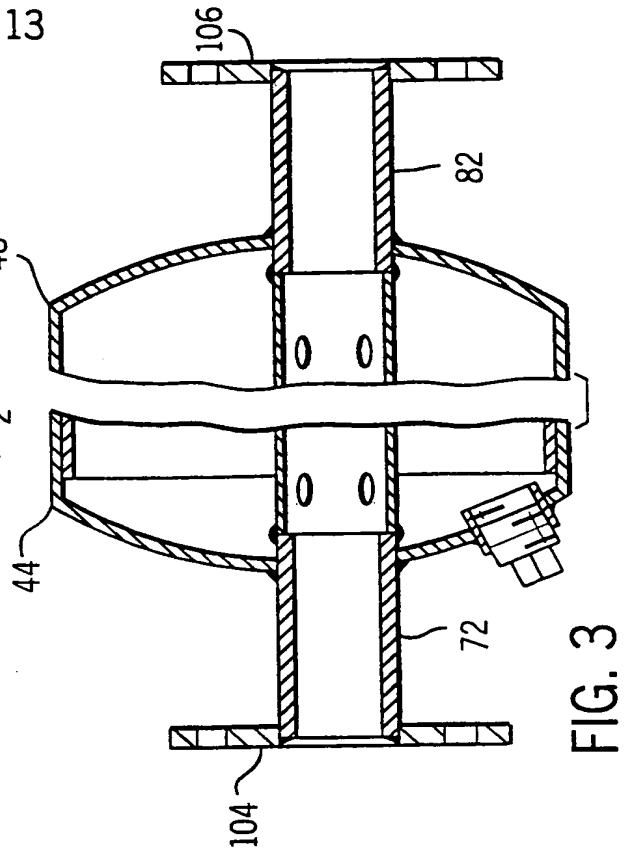


FIG. 3

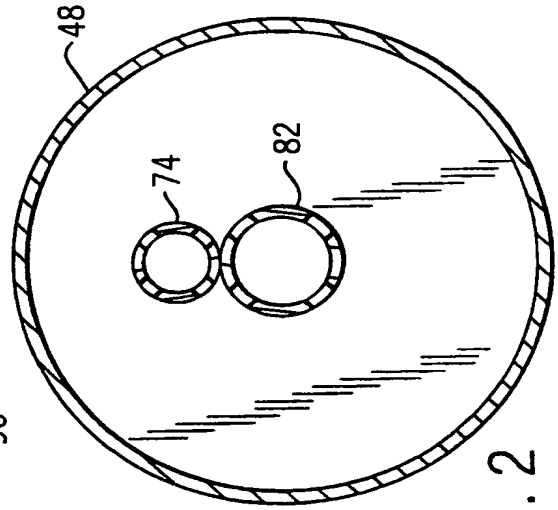


FIG. 2

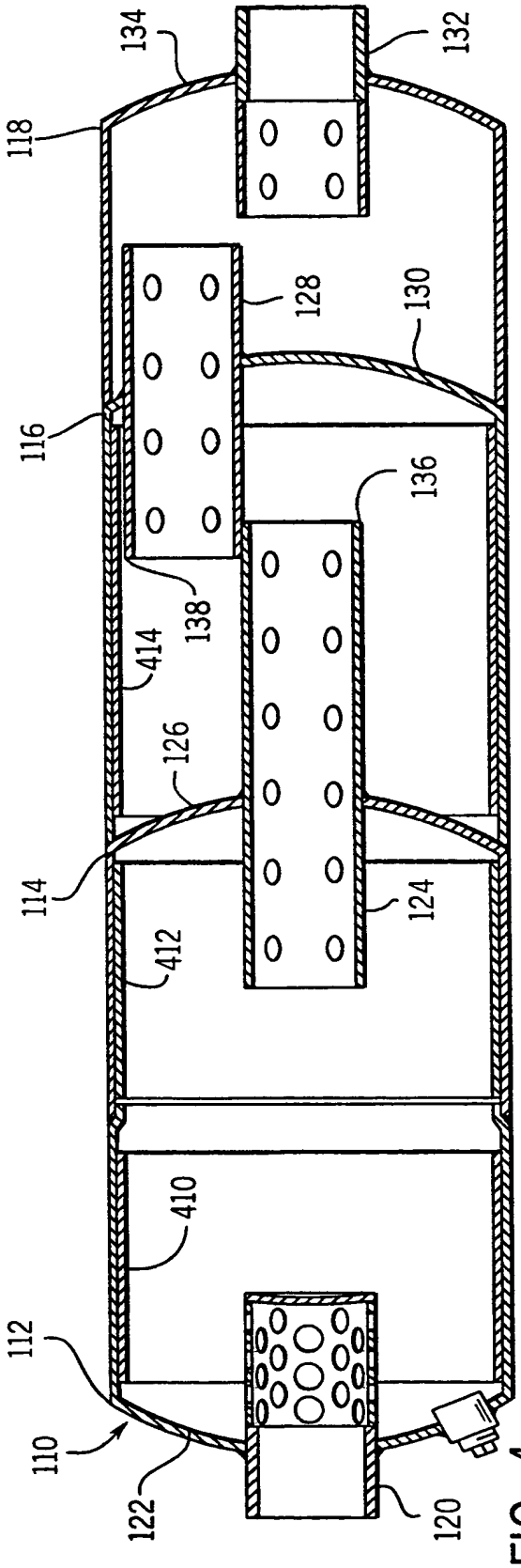


FIG. 4

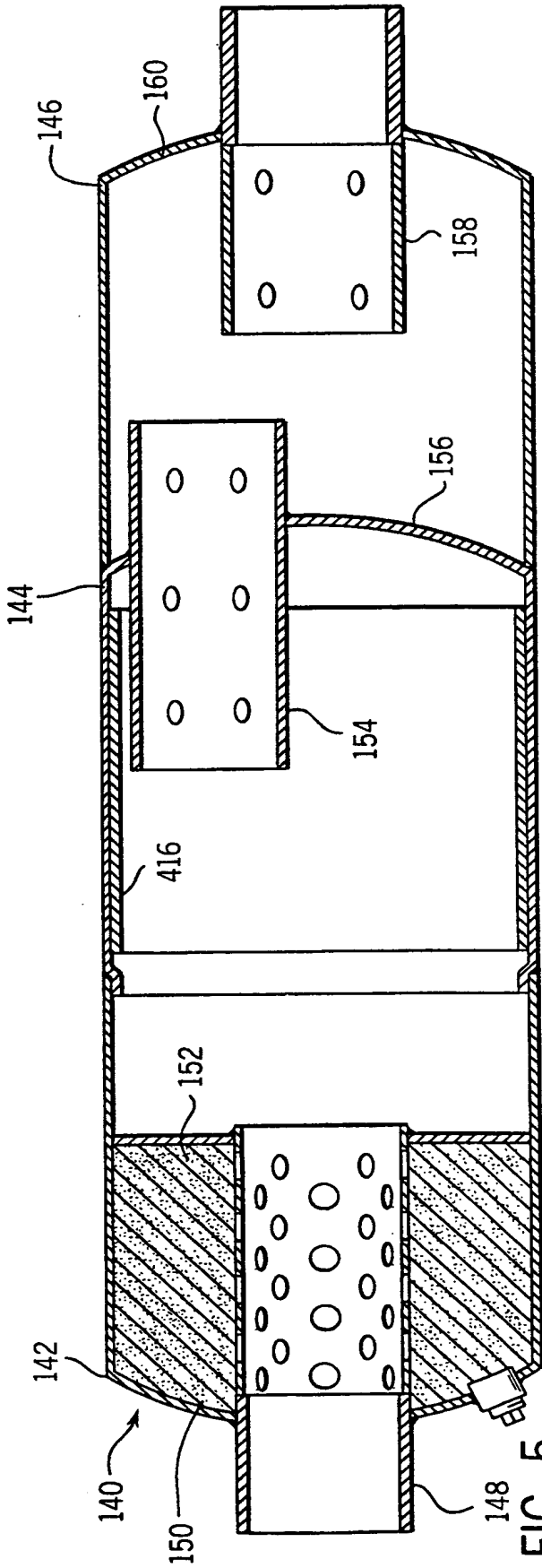


FIG. 5

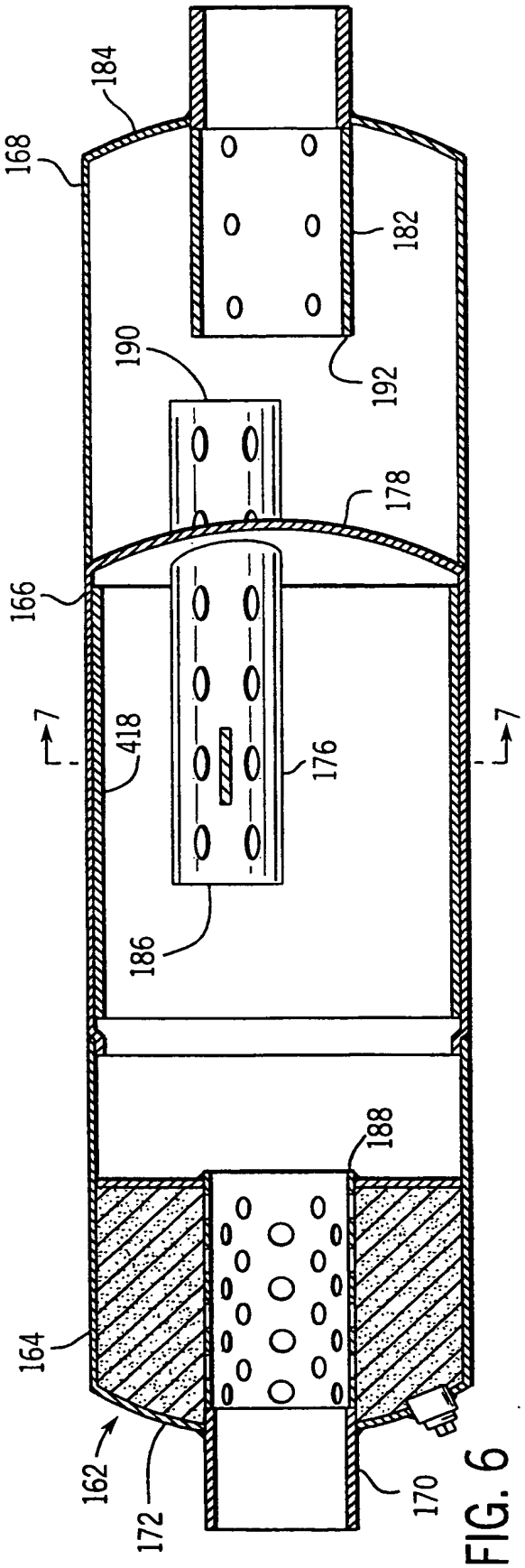


FIG. 6

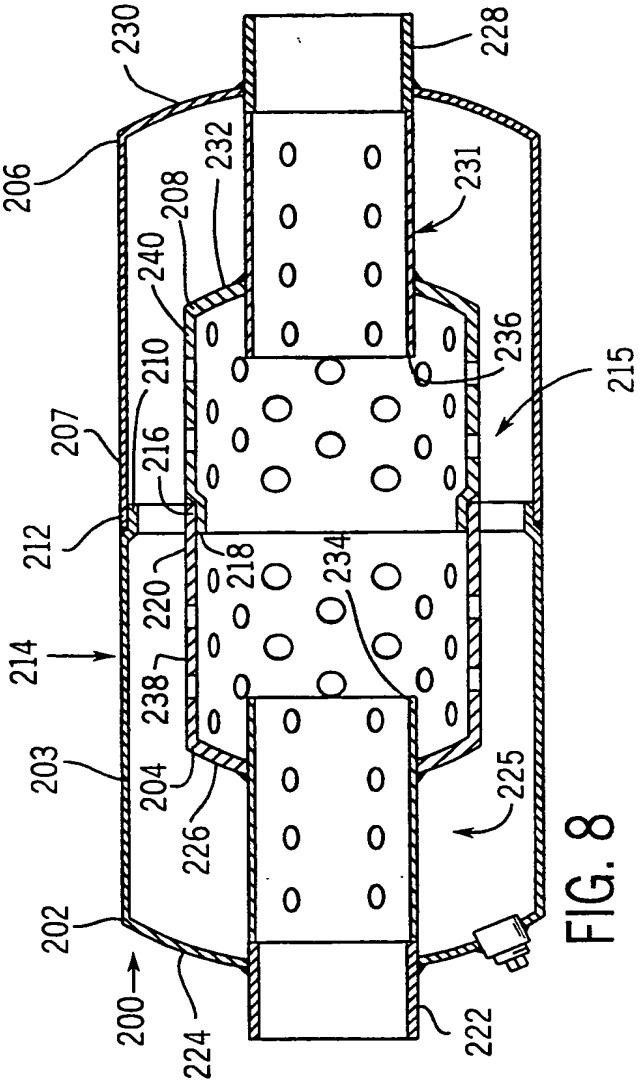


FIG. 8

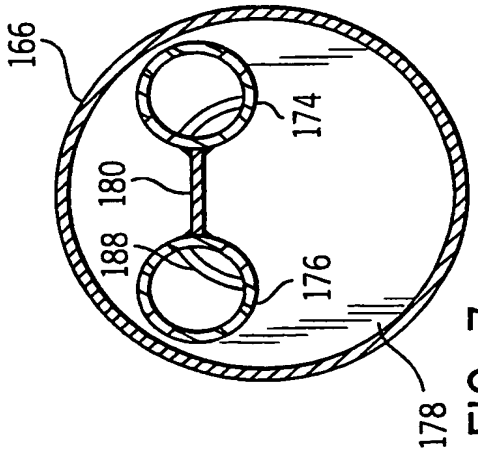


FIG. 7

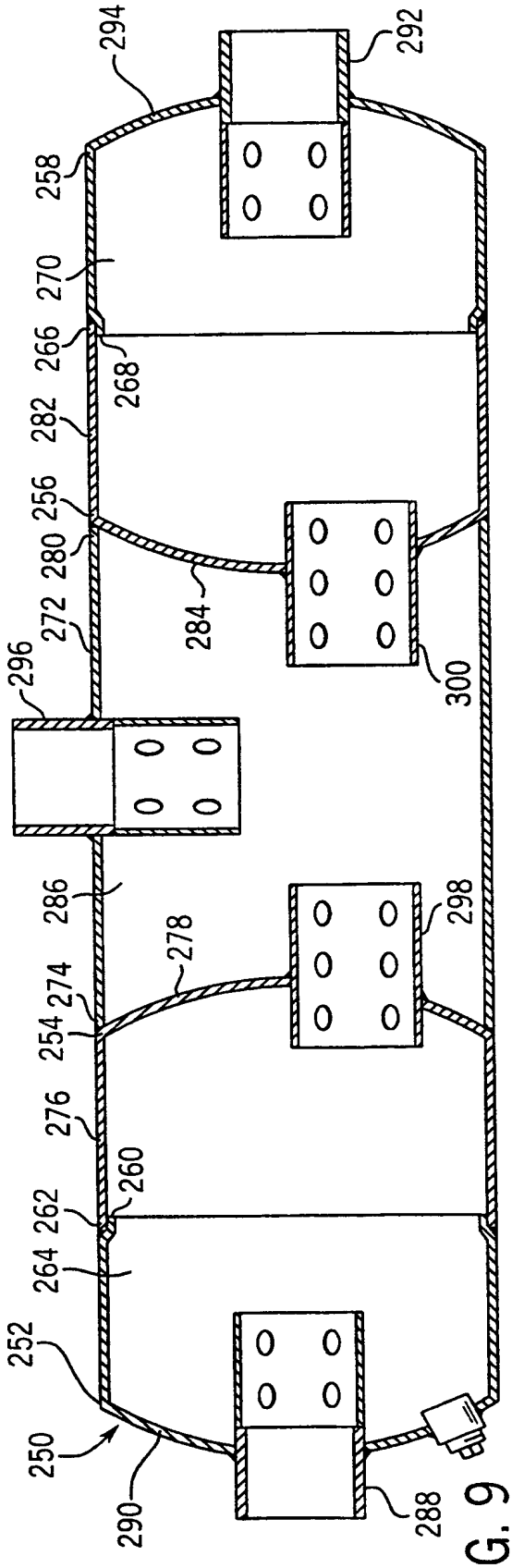


FIG. 9

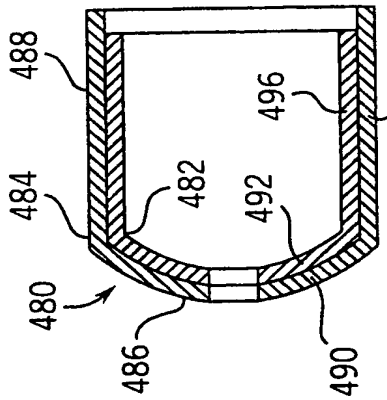


FIG. 26

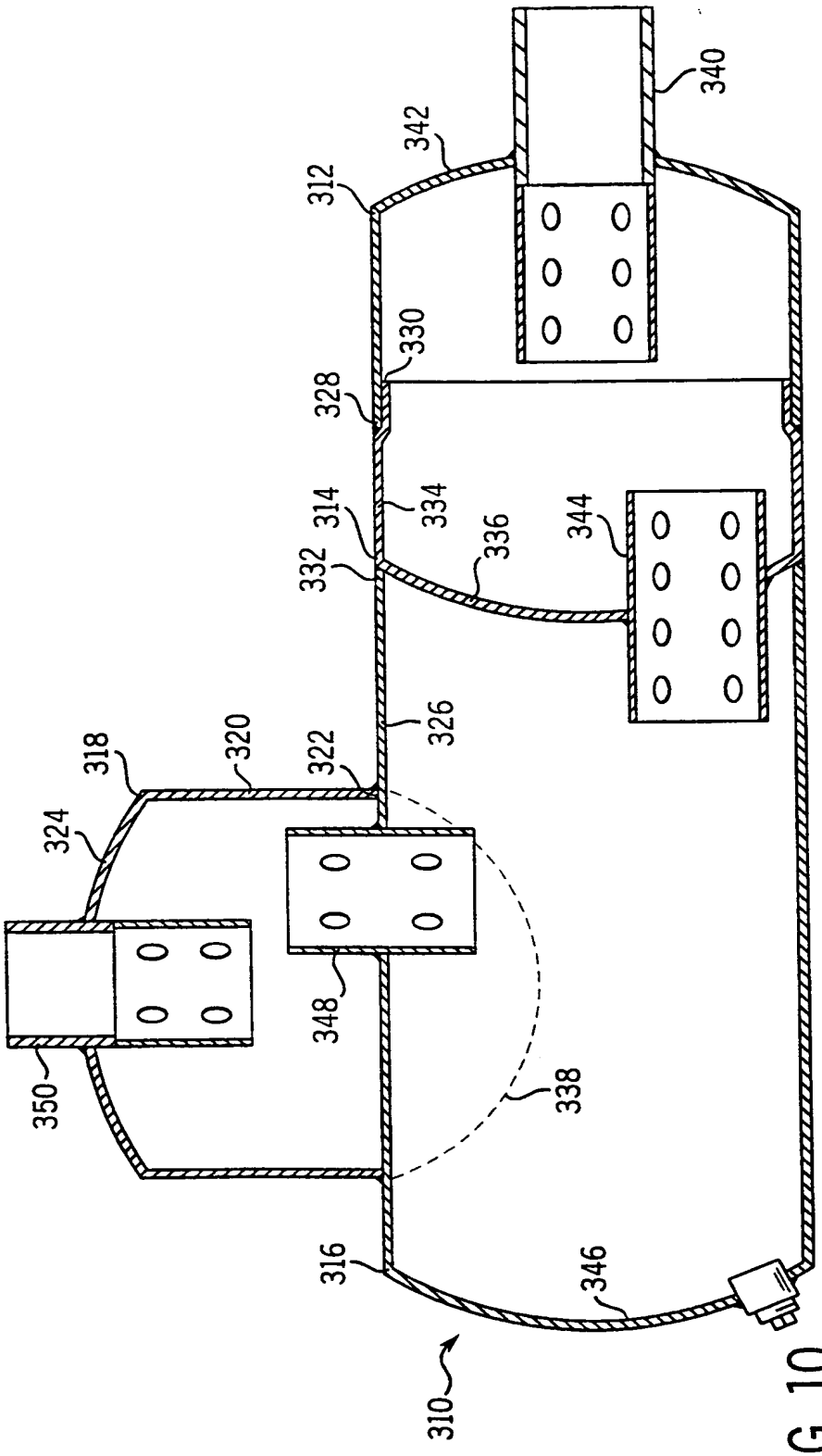


FIG. 10

FIG. 11

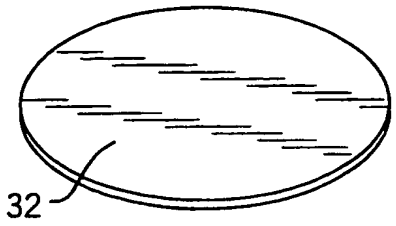


FIG. 12

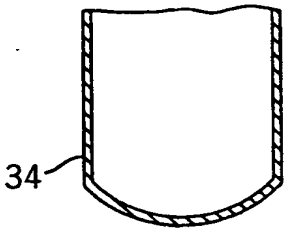


FIG. 13

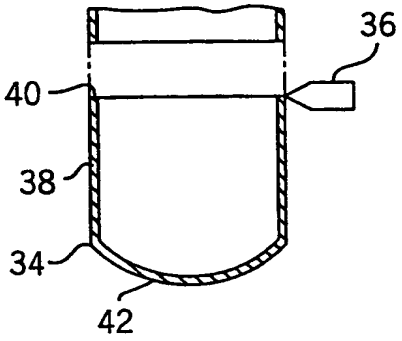
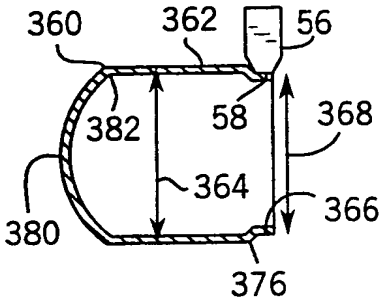


FIG. 14



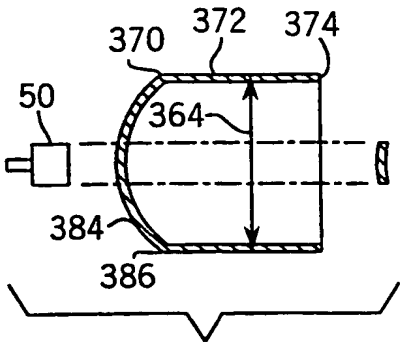
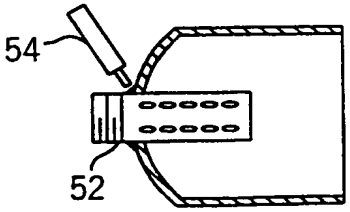


FIG. 15

FIG. 16



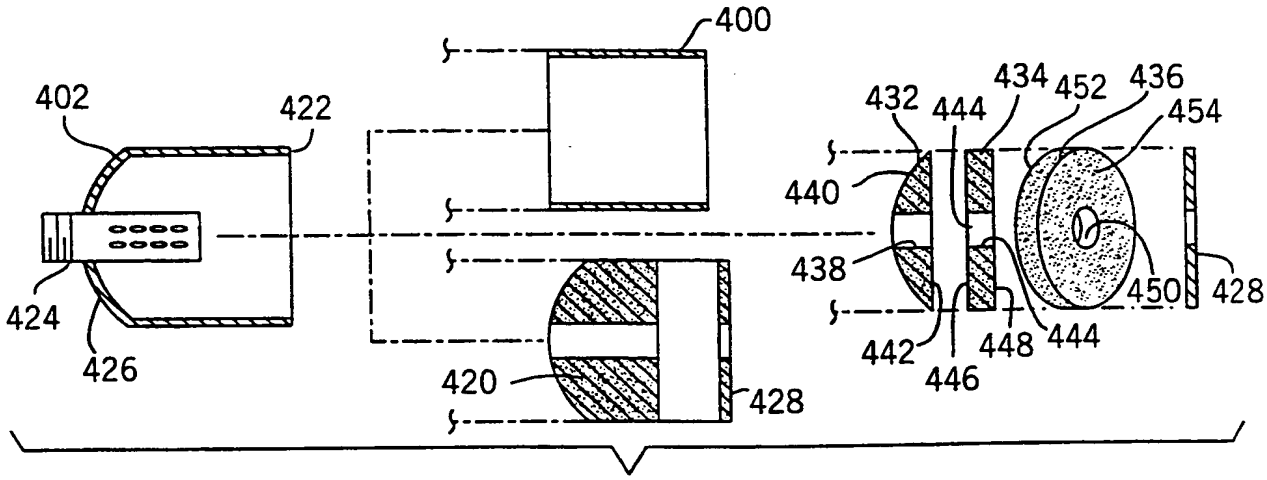


FIG. 17

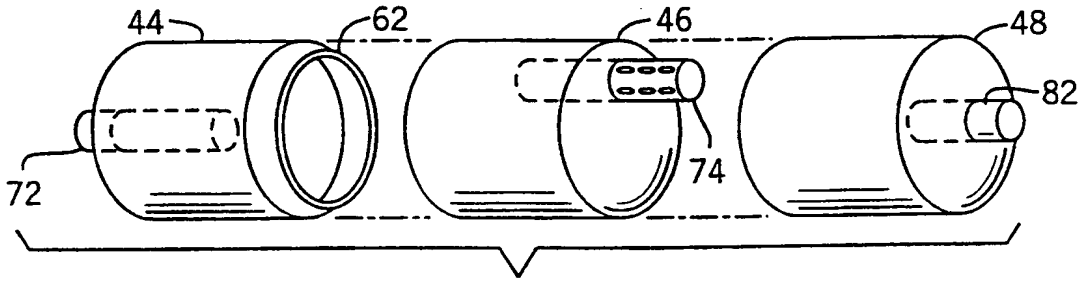


FIG. 24

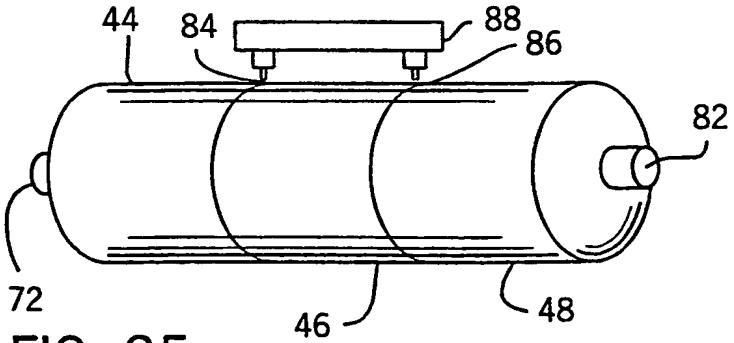


FIG. 25

FIG. 18

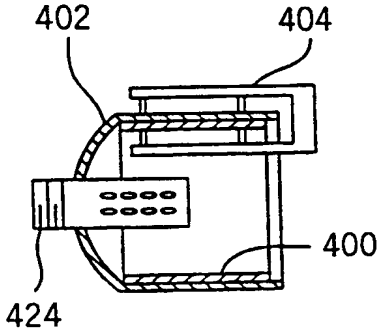


FIG. 19

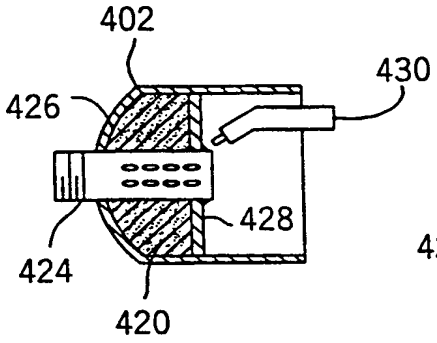
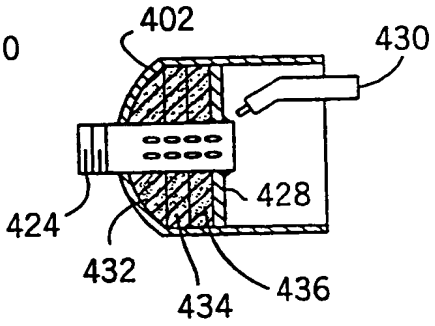


FIG. 20



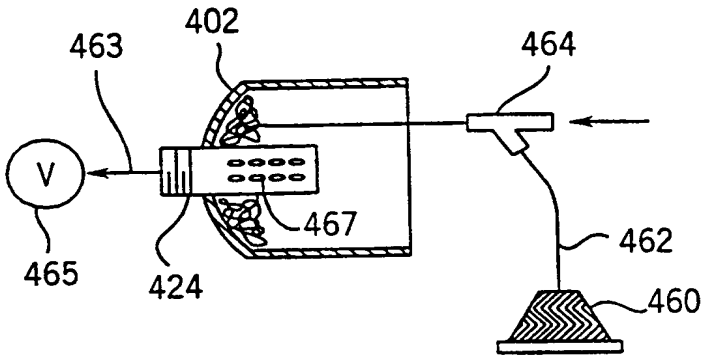


FIG. 21

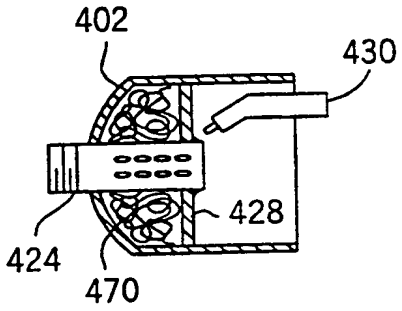


FIG. 23

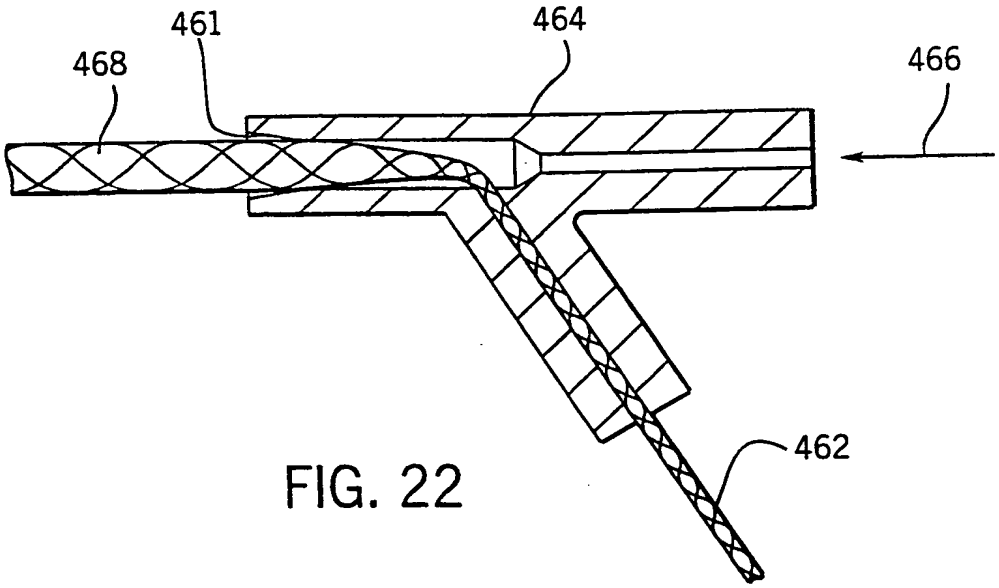


FIG. 22

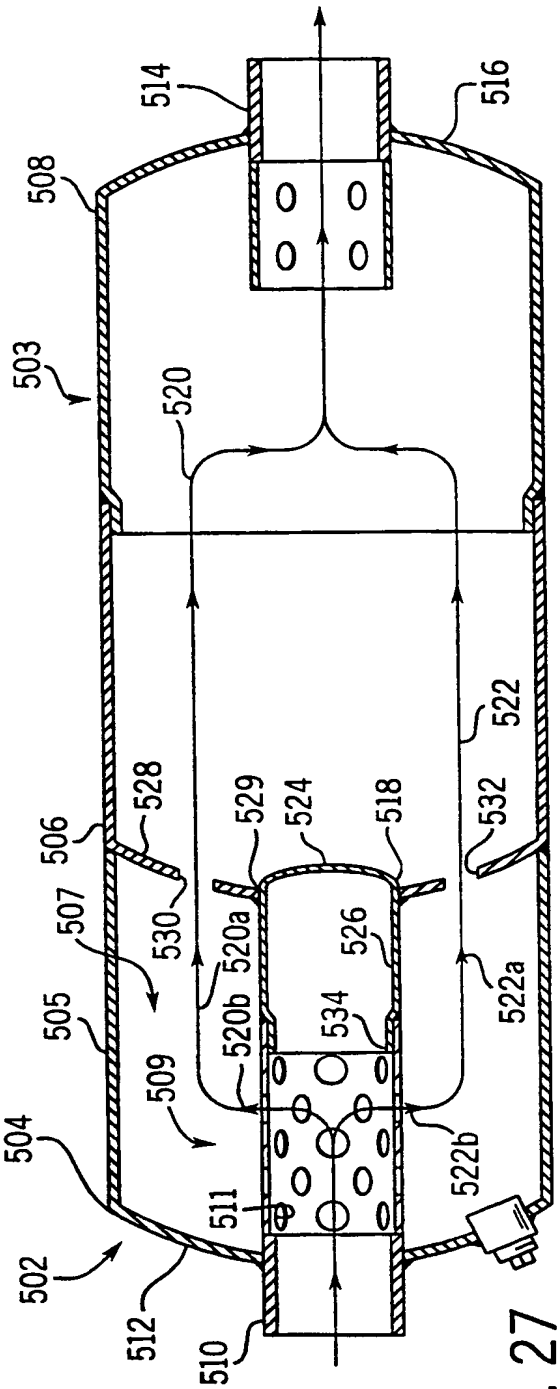


FIG. 27

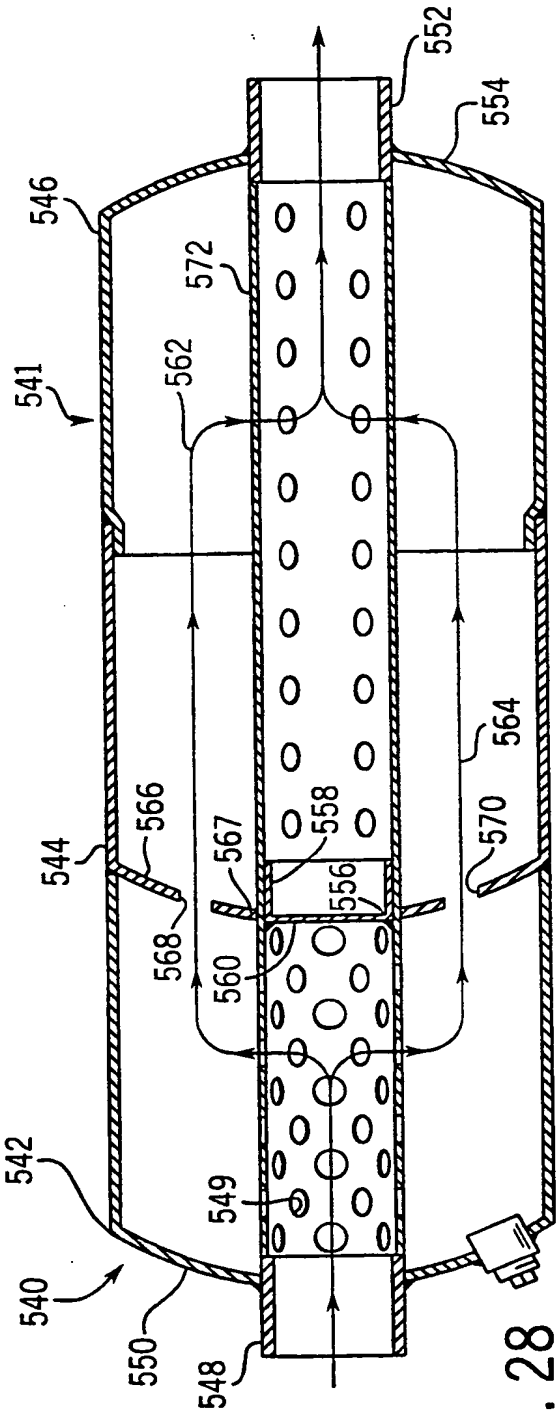


FIG. 28

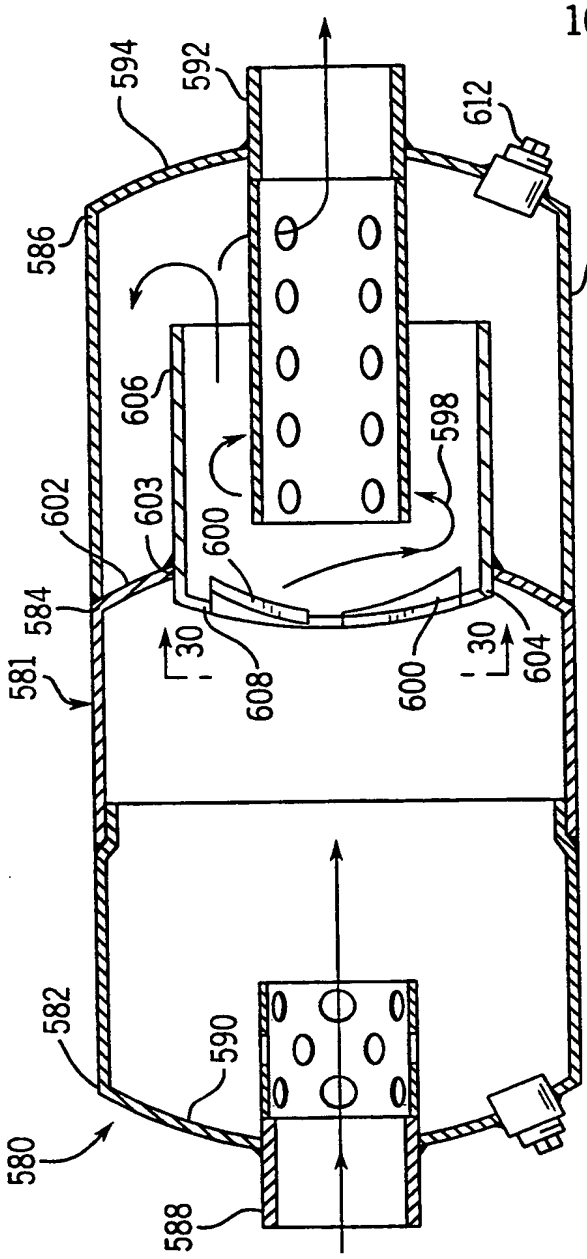


FIG. 29

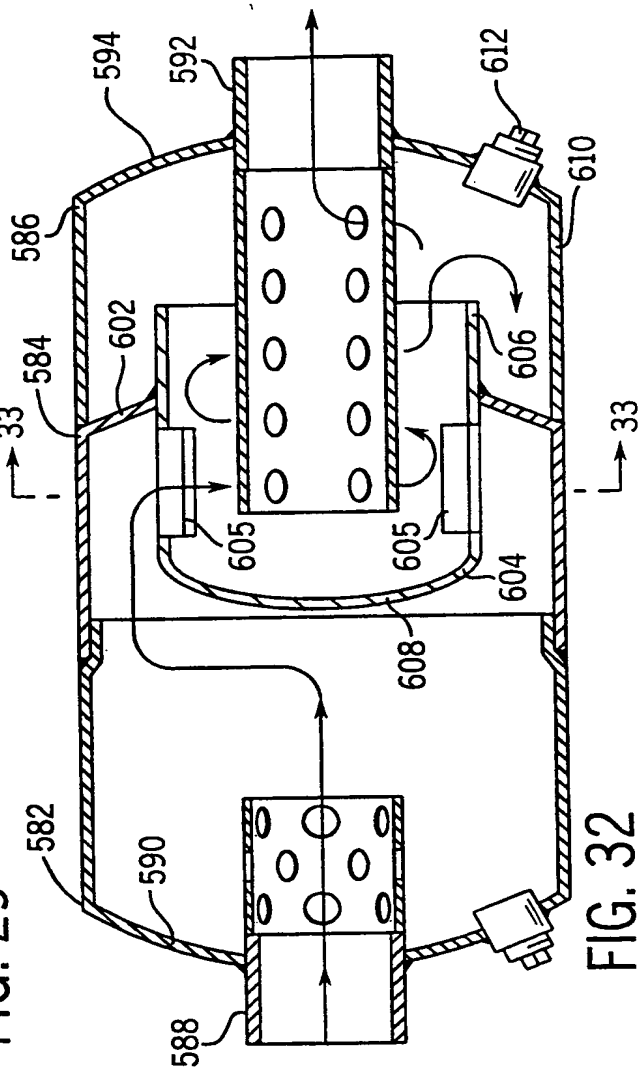


FIG. 32

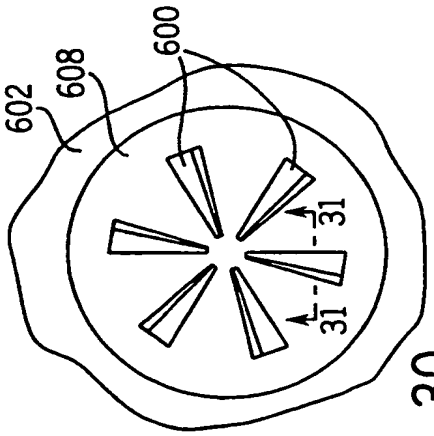


FIG. 30

FIG. 31

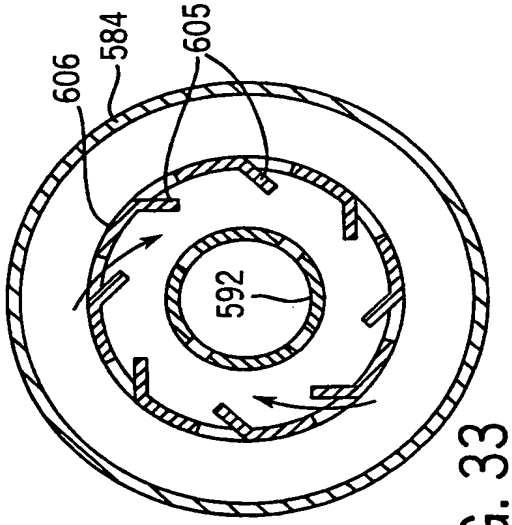


FIG. 33

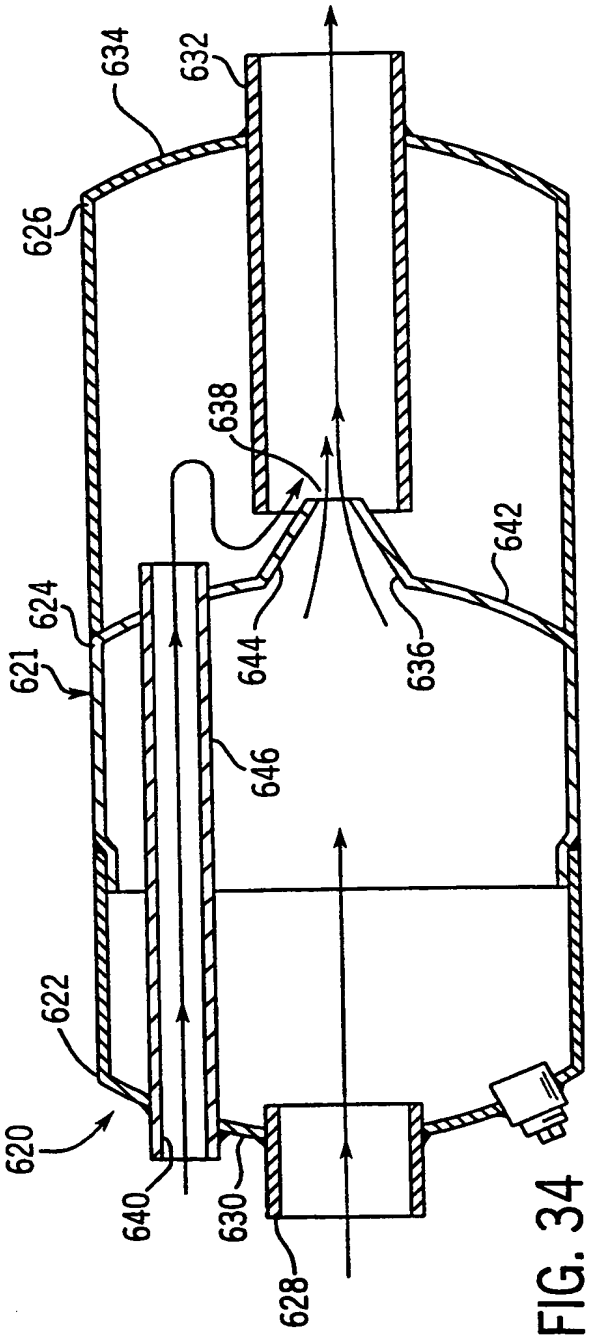


FIG. 34

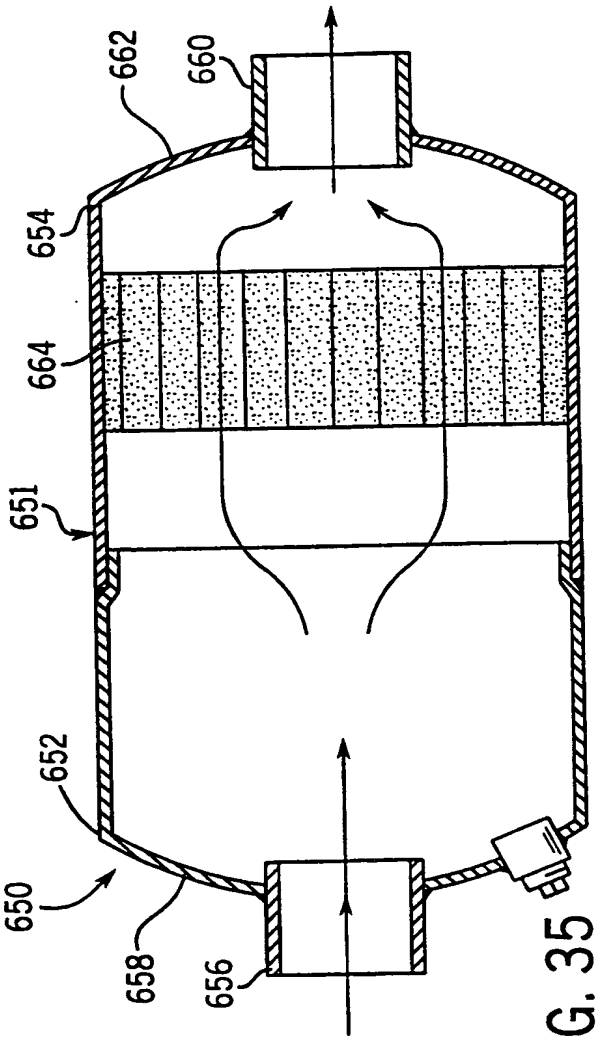


FIG. 35

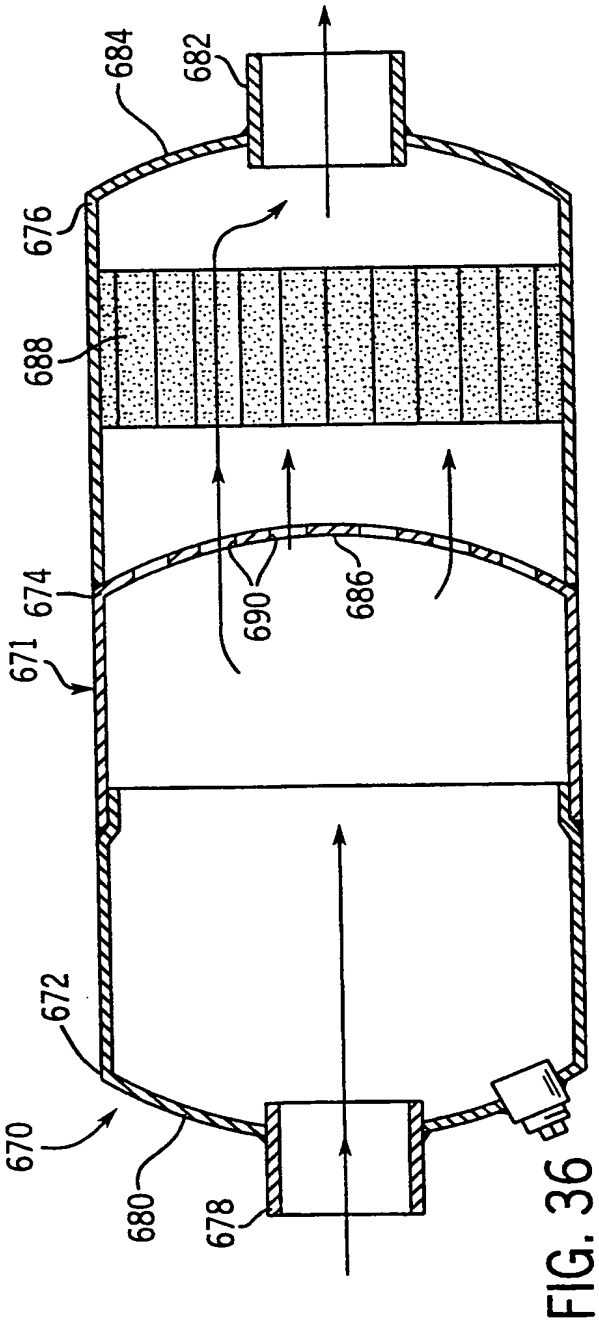


FIG. 36

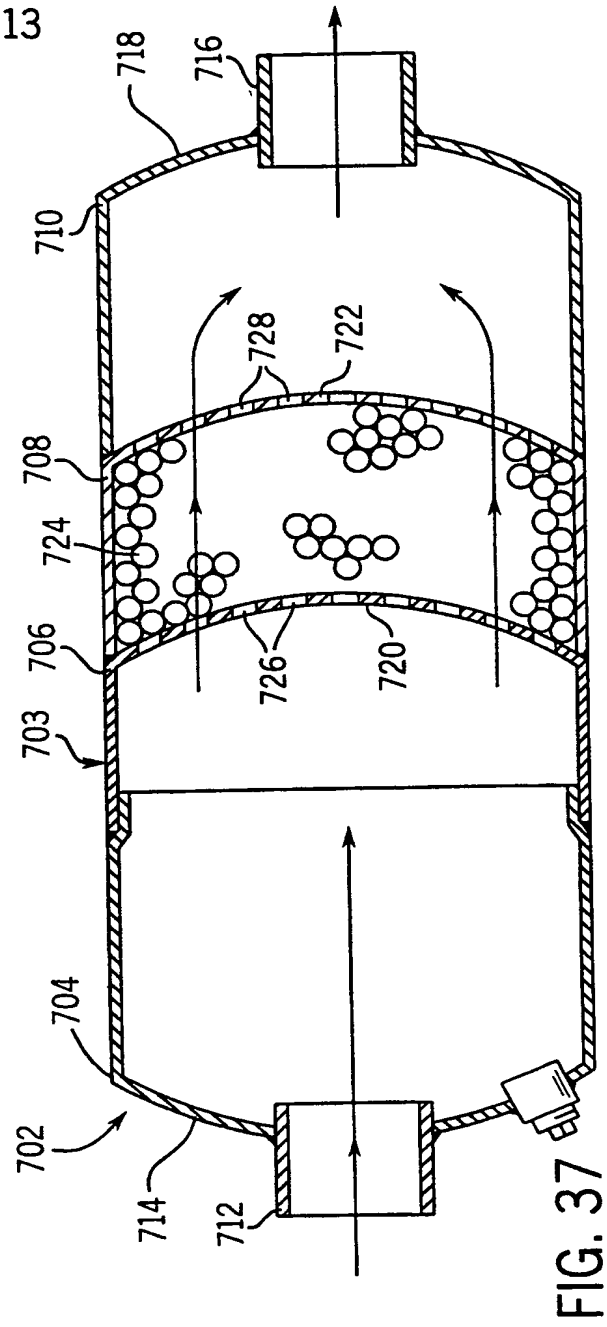


FIG. 37

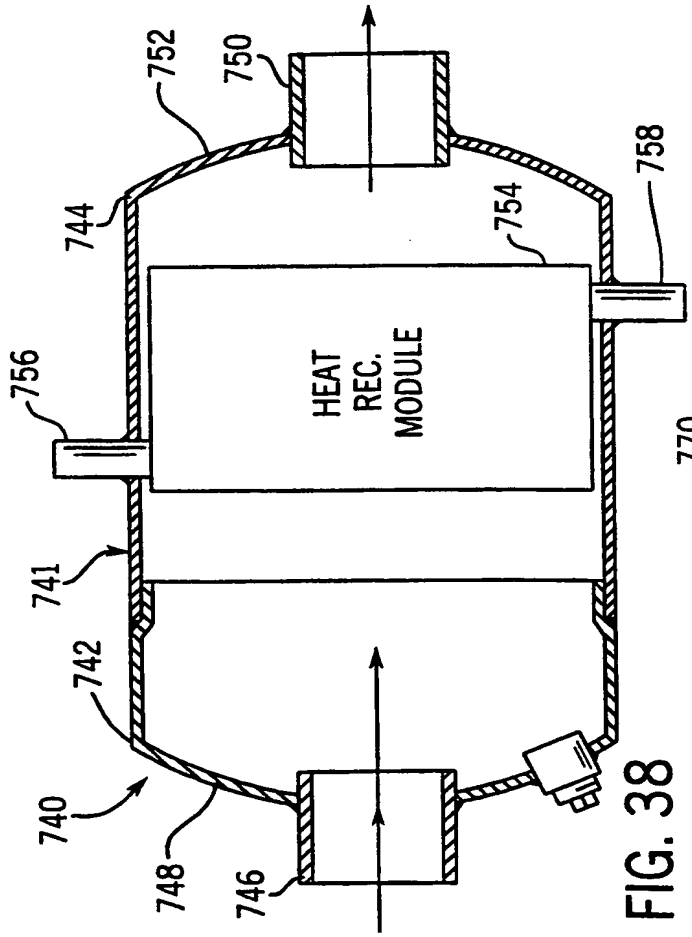


FIG. 38

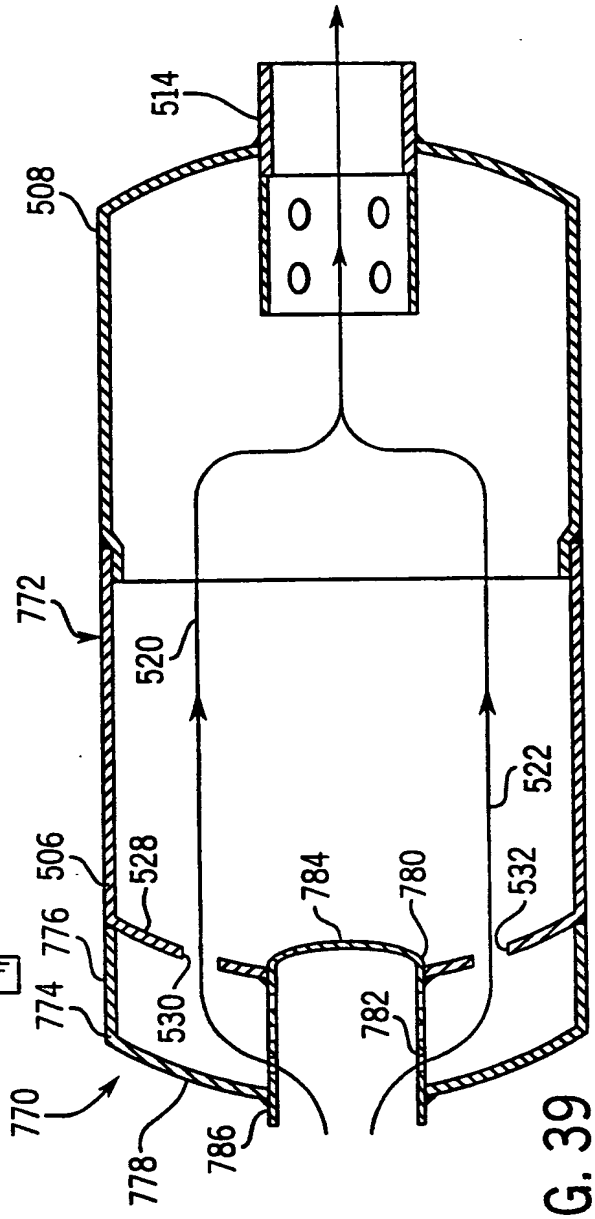


FIG. 39

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/13451

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :F01N 7/18
US CL :181/282
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 181/243, 255, 269, 272, 282

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2,107,588 A (SMITH) 08 February 1938 (08.02.38), see entire document	1-105
A	US 4,172,508 A (MOSS et al.) 30 October 1979 (30.10.79), see entire document	1-105
A	US 3,827,531 A (HANSEN) 06 August 1974 (06.08.74), see entire document	1-105
A	US 4,102,430 A (WILSON) 25 July 1978 (25.07.78) see entire document	1-105

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 27 OCTOBER 1998	Date of mailing of the international search report 29 DEC 1998
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer Khanh Dang Telephone No. (703) 308-0211

Form PCT/ISA/210 (second sheet)(July 1992)*